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QUANTIFICATION OF POLLUTANTS IN AGRICULTURAL RUNOFF

James N. Dornbush, et al

South Dakota State University
Brookings, South Dakota

February 1974

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16. Abstract

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Runoff samples from 108 snowmelt events and 36 rainfall events were collected. Equipment fabrication and installation resulted in some incomplete data for the initial year, but successful monitoring of each runoff event was accomplished thereafter.

Sediment losses were considerably lower than anticipated. Pesticide concentrations were low in both water and sediment samples, and were usually less than the analytical test limits. Coliform and fecal levels were consistently greater than accepted surface water quality criteria. Most of the nutrients were found to be soluble and/or associated with snowmelt runoff. (EPA)

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Abstractor Leland L. Harms

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IN
AGRICULTURAL RUNOFF

by

James N. Dornbush
John R. Andersen
Leland L. Harms

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Ronald R. Ritter
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ABSTRACT

Surface runoff from snowmelt and rainfall in eastern South Dakota was measured during a three year period. The size of the research sites ranged from 7.18 to 18.69 acres, and all sites had crops of corn, oats, pasture or hayland. Composite samples of the runoff were used for various chemical, physical and biological determinations.

Runoff samples from 108 snowmelt events and 36 rainfall events were collected. Equipment fabrication and installation resulted in some incomplete data for the initial year, but successful monitoring of each runoff event was accomplished thereafter.

Sediment losses were considerably lower than anticipated. Pesticide concentrations were low in both water and sediment samples, and were usually less than the analytical test limits. Coliform and fecal levels were consistently greater than accepted surface water quality criteria. Most of the nutrients were found to be soluble and/or associated with snowmelt runoff.

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CONTENTS

Page

Abstract ii

List of Figures iv

List of Tables vi

Acknowledgments viii

Sections

I Conclusions 1

II Recommendations 3

III Introduction 4

IV Review of Literature 6

V Research Sites 22

VI Field Methods 39

VII Laboratory Methods 47

VIII Data and Results 55

IX References 90

X Appendices 96

FIGURES

No.		Page
1	General Site Locations	24
2	Site 1	26
3	Site 2	28
4	Site 3	30
5	Site 4	32
6	Site 7	34
7	Site 8	36
8	Site 9	38
9	Front View of Field Installation	40
10	Side View of Field Installation	40
11	Interior View of Sampler	44
12	View of Solenoid Controlled Clamping System for the Sampler	44
13	Type F Water Level Recorder With Modifications to Activate Automatic Sampler	46
14	View of Level Recorder Showing Mounting of Plastic Strip	46
15	Flow Diagram For Treatment and Analysis of Samples During Phase I	48
16	Flow Diagram For Snowmelt Determinations During Phase II	50
17	Annual Runoff Patterns for Phase II	58

FIGURES (continued)

No.		Page
18	Distribution of Rainfall Events	60
19	Hydrograph Comparison of a Low Intensity Storm and a High Intensity Storm	62
20	Total Coliforms in Snowmelt Runoff	73
21	Fecal Coliforms in Snowmelt Runoff	75
22	Fecal Streptococcus in Snowmelt Runoff	76
23	Bacteriological Indicators in Rainfall Runoff From Cultivated Fields	77
24	Breakdown of Total Runoff Contributions For 1971 and 1972	87

TABLES

No.		Page
1	General Quality of Surface Runoff from Nonpoint Discharges	7
2	Nutrients in Rural Runoff	11
3	Summary of Analysis of Variance of Freezing Effects on Analytical Determinations of Snowmelt Samples	51
4	Autoanalyzer Methodology	53
5	Precipitation Summary at Research Sites From Mid-March to Mid-November	56
6	Frequency of Runoff from Rainfall	56
7	Biochemical Oxygen Demand and Related Factors for Agricultural Runoff	64
8	Concentrations of Characteristics of Snowmelt Runoff for Phase I	66
9	Recommended Limits of Bacteriological Indicators in Surface Waters	71
10	Bacteriological Data from Rainfall Runoff on Uncultivated Fields	78
11	Number of Samples Grouped in Ranges of Pesticide Concentrations for Filtered Runoff Samples	80
12	Number of Samples Grouped in Ranges of Pesticide Concentrations for Sediment Samples	82
13	Mean Concentrations of Runoff Parameters by Land Use	83
14	Yearly Runoff Contributions of Runoff Parameters by Land Use	86

TABLES (Continued)

No.		Page
15	Soluble Fraction of COD, Phosphorus and TKN of Snowmelt and Rainfall Runoff from Research Sites	89

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SECTION I

CONCLUSIONS

1. Considerable quantities of nutrients were present in the agricultural runoff, and these have important implications regarding lake eutrophication. Nutrient losses ranged from 0.03 to 3.0 lb/acre/yr of nitrogen and from 0.01 to 0.72 lb/acre/yr of phosphorus. The form of the nutrients is also of consequence. Most of the annual nutrient load comes from snowmelt runoff, and a large percentage is in a soluble form. In areas comparable to those of this study, soil conservation practices aimed primarily at reducing soil losses without substantially reducing surface runoff, particularly from melting snow, will probably not be effective for retarding lake eutrophication from the nutrients in agricultural runoff.

2. Annual soil losses were much lower than anticipated. Soil losses ranged from less than 10 lb/acre/yr to a maximum of less than 1000 lb/acre/yr. While runoff due to rainfall accounted for nearly all (93.7%) of the sediment losses, it accounted for only about one-half of the soluble nutrient species.

3. Most of the sediment in runoff waters was from cultivated fields with relatively small amounts originating on areas in permanent grass. The bulk of the soil losses, as well as losses of those constituents associated with the soil, occurred during short duration, high intensity rain storms. Almost all the soil lost during the 2 year study can be attributed to approximately the 1/3 of the runoff which was caused by rainfall. The instantaneous concentration of soil in the rainfall was directly related to the flow rate.

4. Total coliform and fecal coliform densities in runoff frequently exceed those limits specified in some surface water quality standards. However, runoff waters from agricultural lands are probably not a potential health hazard and FC/FS ratios should also be considered. Total coliform counts are usually greater than fecal streptococcus levels. The highest total coliform and fecal streptococcus counts for snowmelt runoff were attributed to cultivated fields.

5. Pesticide concentrations in runoff waters from rainfall and snowmelt were very low with most samples having concentrations below the analytical test limits of 0.05 ppb for aldrin, DDE, dieldrin, lindane, heptachlor, heptachlor epoxide, and endrin and 0.10 ppb for DDT, DDD, atrazine and methoxychlor. Most sediment samples also had pesticide concentrations below the analytical test limits.

6. Each site consistently had more snowmelt runoff events than rainfall runoff events. Fields with permanent grass cover had runoff quantities comparable to those of cultivated fields although almost all of the runoff occurs from snowmelt for fields in permanent grass.

7. Fall plowing reduces the amount of snow retained on the fields over the winter months. Although runoff was reduced, this practice appeared to increase the erosion potential from wind.

8. Rainfall runoff was an infrequent and unpredictable event and can be expected to occur only a few times each year, generally during spring and early summer when crop cover is light and rainstorms are more frequent.

9. When comparing individual parameter concentrations from rainfall and snowmelt runoff, the runoff from cultivated areas showed wider variations than runoff from uncultivated areas.

SECTION II

RECOMMENDATIONS

This investigation has demonstrated that surface runoff from cultivated fields, permanent grassland and pasture in the upper great plains area is frequently of a quality that would exceed standards of many receiving streams and lakes. For some constituents such as phosphorus, concentrations exceeded recommended standards for treated wastewater effluents. Recognizing that the quality of agricultural surface runoff is highly variable and dependent on many factors indigenous to the watershed area, the following recommendations are offered.

1. Additional monitoring of surface runoff from large agricultural areas should be performed throughout the nation. Estimates of some pollutant losses from small plot studies do not appear to be representative of larger drainage areas.

2. Evaluation of routine stream monitoring data should emphasize periods of predominately surface runoff as contrasted with periods of appreciable groundwater inflow to establish pollutant contribution from non-point sources. Review of basic hydrologic information for any region should reveal the periods when surface runoff is most frequent.

3. In predominantly agricultural regions, consideration should be given to establishing treated effluent quality limits at concentrations equal to that of surface runoff from the indigenous area depending upon the quantity and frequency of runoff events. This consideration would apply particularly to concentration limits on plant nutrients for control of undesirable algal growths.

SECTION III

INTRODUCTION

GENERAL

The problems of pollution from agricultural practices are indeed complex but those of defining pollution from agriculture may be even more involved. Agricultural runoff from large areas collects to create the rivers or lakes, the pollution of which is the cause of concern. Consequently, agricultural runoff serves as the baseline of available water quality whether it originates from forest, pastures, or croplands. Yet, very little information is presently available concerning the concentrations of pollutants in this baseline, agricultural runoff.

Information regarding the quality of agricultural runoff has been relatively limited in comparison to that relating to most other industrial sources of water pollution. Much of the research with agricultural runoff has been conducted with small test plots which simulated agricultural lands and often related to only one particular water-carried pollutant such as sediment. Information concerning runoff quality in the upper great plains region was almost entirely lacking, and research to more fully determine the characteristics of agricultural runoff was needed. This research project was initiated to meet that need.

OBJECTIVE

The general objective of this project was to quantify the pollutional constituents of agricultural surface runoff. It was desired to determine contributions of constituents in terms of quantity per unit acre per unit time for various land uses.

It was also considered important to know the reduction in waste discharges that may be obtained by sedimentation. Determination of the fraction of pollutional constituents associated with the suspended solids or sediment load carried with the surface runoff would be an objective aimed at relating the potential of soil conservation practices to the improvement of the runoff quality.

In as much as possible, it was also an objective of this study to relate the quality of surface runoff to numerous factors peculiar to specific drainage basins. This would allow extrapolation of the findings to drainage basins in other areas having different climatic conditions, other land uses, and various physical factors.

SCOPE OF THIS RESEARCH

This project pertained to surface runoff from cultivated fields, permanent grass and alfalfa lands, and grazed pasture. The runoff from confined feeding operations was not evaluated. All field conditions were natural and uncontrolled. Simulated rainfall was not used, and an attempt was not made to influence the land operators with respect to land management practices.

Sampling was executed any time that runoff occurred. Manual sampling and flow measuring were employed for spring runoff, while automatic sampling and flow measuring equipment were used during rainfall events. Samples were brought into the laboratory and a composite sample was made for each site. All the bacteriological, physical and chemical determinations were then conducted on these composite samples.

SECTION IV

REVIEW OF LITERATURE

GENERAL QUALITY

Estimates of annual losses of sediment and nutrients from rural areas tend to stagger one's imagination. Approximately 4 billion tons of sediment are washed into United States streams each year (1). Eliassen and Tchobanoglous estimated nitrogen and phosphorus contributions from rural agricultural land at 1,500 to 15,000 and 120 to 1,200 million pounds per year, respectively. Annual contributions from rural non-agricultural land were estimated as 400 to 1900 million pounds of nitrogen and 150 to 750 million pounds of phosphorus (2).

The majority of investigators who have studied agricultural runoff have conducted stream surveys and the data are generally limited to nutrients contributions. However, a few researchers have compiled general quality data from agricultural surface runoff (3) (4) (5), and these data are presented in Table 1 along with data from an urban area for comparison (6).

A 173 acre cultivated site in eastern South Dakota was sampled by Benson (3) and McCarl (4) during 1969 and 1970. Samples were preserved by freezing without presenting data to verify the method used. The quality of both snowmelt and rainfall runoff was recorded. A summary of their data is shown in Table 1. Total annual contributions were computed by McCarl for the 1970 runoff season (4). Annual loads of 2,040 lb/acre of suspended solids, 6.9 lb/acre of BOD, 246 lb/acre of COD, 8.4 lb/acre total nitrogen and 0.07 lb/acre of total phosphorus were reported.

Weibel et al. (6) reported on the general quality of runoff water from a 27 acre residential area in urban Cincinnati. About 730 lb/acre/yr of SS were measured of which 22% were volatile. The BOD and COD were 33 lb/acre/yr and 240 lb/acre/yr, respectively.

Weidner et al. (5) obtained runoff quality data from two 1.5 acre watersheds near Coshocton, Ohio and also from a 5-acre apple orchard at Ripley, Ohio. Most of the material losses occurred during the summer months as a result of high intensity rainstorms. The organic losses, as measured by BOD and COD, were small. BOD values ranged

TABLE 1. - General Quality of Surface Runoff from Nonpoint Discharges

Item	Benson (3)	McCarl (4)	Weibel, *et al.* (6)	Weidner, *et al.* (5)
Land use	Farmland	Farmland	Residential	Research plots and apple orchard
BOD, mg/l	5 - 30	3 - 15	2 - 84	3 - 8.4
BOD, lb/acre/yr	-	6.9	33	3.7 - 120
COD, mg/l	50 - 360	70 - 780	20 - 610	40 - 68
COD, lb/acre/yr	-	246	240	27.8 - 1300
Solids, mg/l	90 - 5000 SS	180 - 6000 SS	5 - 1200 SS	500 - 575 TS
Solids, lb/acre/yr	-	2,040 SS	730 SS	185 - 13,200 TS
Total phosphorus, mg/l	0.26 - 2.4 Soluble P	0.04 - 0.60	0 - 1.4 Soluble P	0.42 - 0.98
Total phosphorus, lb/acre/yr	-	0.07	0.8 Soluble P	0.36 - 9.0
Org. N + NH_3,mg/l	1.3 - 20.3	2.8 - 17	0.1 - 7	-
Total nitrogen mg/l	-	12.9 - 33.2	0.2 - 9	4.9 - 9.0
Total nitrogen, lb/acre/yr	-	8.4	8.9	0.8 - 237

from 3.7 to 120 lb/acre/yr and COD losses ranged from 27.8 to 1300 lb/acre/yr.

SOIL LOSSES

Soil erosion by water is a common geological phenomenon. It accounts for many of the variations in topography of the land about us. Normal processes of erosion work slowly and continuously. Accelerated erosion, which is more rapid than normal erosion, has become a cause for concern in recent decades.

Walker and Wadleigh discussed water pollution as it relates to land runoff. They estimated that the sediment yield of the Mississippi River Basin averages 390 ton/sq mi/yr. Soil losses are not the only consideration. They also estimated that each 1000 tons of sediment carries about 1000 pounds of phosphorus fixed to its surface (7). Nutrients lost from the land are often greater than expected because the finer and more fertile soil particles are sorted out and washed away (8).

Several investigators have obtained data regarding soil losses from various sized fields and plots. McGuinness et al. described the eight small natural watersheds which the Agricultural Research Service had been evaluating near Coshocton, Ohio from 1945 to 1956 (9). The watersheds were matched into four pairs and subjected to a four year rotation of corn, wheat, and two years of meadow.

The study compared the effects of improved farming practices with prevailing farming methods. The improved practices decreased soil and water losses except during extremely intense storms. Average peak rate reductions of water losses for the improved methods were 0.82 in./hr for corn, 0.22 in./hr for wheat, and 0.04 in./hr for meadow (9). Weidner et al. reported long term, average soil losses as high as 7.7 ton/acre/yr for these same watersheds. (14).

Data from small plots (13.3 ft by 72.6 ft) in western Minnesota were reported by Holt (21) and Timmons et al. (22). Two-year average soil losses were given by Holt at 0 to 7 ton/acre/yr (10), and average annual losses of 2.2 to 21.4 ton/acre were reported for 1961 to 1967 (11).

Sediment from some larger watersheds was measured by McCarl (4) and Dragoun and Miller (12). An annual load of about 1 ton/acre was received from a 173 acre area under cultivation (4). A 481 acre watershed being farmed by conventional methods was compared with a 411 acre watershed on which improved farming practices such as terraces and grassed waterways were used. About 75% of the unimproved acreage was cultivated, while 60% of the improved land was cultivated (12). Over a four year period, the sediment yield for the unimproved area was 8.4 ton/acre and 4.5 ton/acre for the improved field. They concluded that sediment reductions of 50% or more could be realized by implementing soil conservation measures. The reduction was primarily due to a decrease in water yield. Runoff on the unimproved land averaged 3.9 in./yr while the average runoff from the improved acreage was 2.9 in./yr (12).

The Department of Agronomy at Cornell University conducted a three part study to evaluate the factors which control soil and nutrient movement from the land. An artificial rainfall simulator was used on small test plots for one part of the study, and the largest erosion loss was from continuous corn. Another part used larger test plots (0.8 acres each) and natural rainfall conditions. The use of mineral fertilizers resulted in physical deterioration of the soil and subsequently increased surface runoff and soil losses. Incorporating crop residues into the soil was recommended, as well as proper timing of fertilizer applications. The third part of the project was an algal nutrient study. Results from the algal nutrient study were inconclusive (13).

In an attempt to define soil erosion and allow prediction of soil losses, researchers studied specific aspects of the erosion process. The severity of raindrop erosion was investigated by Ellison (14). In particular, he studied the effects of raindrop impact and splash. He speculated that raindrop splash caused most of the severe sheet erosion near hilltops. He concluded that infiltration and runoff were dependent upon raindrop erosion. The use of vegetal canopies and mulches to prevent raindrop erosion was proposed.

Epstein and Grant evaluated some of the factors which define the different erodibility characteristics of soils by using a rainfall simulator on six soil types (15). Soil losses reached a maximum during the first 10 minutes of simulated rainfall for four of the soils, but no peaking effect was noted on the other two soils. They also cast doubts on obtaining realistic erodibility values by using simulated rainfall.

In the early 1960's, researchers were attempting to formulate a soil-loss equation. Rogers et al. used an artificial rainmaking device to generate runoff on small plots, 35 ft to 75 ft long (16). The purpose was to further define coefficients in a soil-loss equation. Most of the variations in soil-loss data were explained by rainfall amounts multiplied by rainfall intensity.

Finally, after more than 20 years of development and based on the work of many contributors, a generally accepted soil-loss equation came into being. This equation is commonly known as the "universal" soil-loss equation. The history of its development, as well as a detailed explanation of the equation, can be found in a handbook compiled by the Agricultural Research Service (17).

The basic soil-loss equation is:

$$A = RKLSCP \qquad \text{Eqn. (1)}$$

Where:
A = Soil-loss per unit area
R = Rainfall factor
K = Soil-erodibility factor
L = Slope-length factor
S = Slope-gradient factor
C = Cropping-management factor
P = Erosion-control practice factor

This equation is based on the data obtained from many small plots scattered throughout the United States and Puerto Rico. It is generally accepted by agricultural people as representing acreage soil losses for cropland east of the Rocky Mountains (17).

NUTRIENTS

The nutrients carried to surface waters by agricultural runoff are an important facet of eutrophication. Information regarding the nutrients in agricultural or rural runoff; and in particular, that which provides quantitative data on nitrogen and phosphorus in agricultural runoff was reviewed.

A major problem of nutrients is the stimulation of growth of algae and other aquatic plants in streams and reservoirs. A report on the various sources of these nutrients was completed by an American Water Works Association Task Group (18). They reported on various sources including domestic, industrial, rural, urban, and farm animal wastes. It was concluded that the single largest contributor of nitrogen and phosphorus to water supplies was agricultural runoff.

Bauman and Kelman warned about requiring cities and industries to install advanced waste treatment equipment without identifying agriculture's contribution to the waste load of a stream (19) (20). They made weekly stream measurements for flow, BOD, COD, SS, turbidity, nitrogen, and phosphorus in the Des Moines River between Boone and Des Moines, Iowa. Exact quantities of nutrients from various sources could not be determined, but they were able to conclude that nitrogen and phosphorus removal from municipal and industrial discharges would be beneficial for flowing streams. However, removal of nitrogen and phosphorus may not benefit impounded waters because the major sources of nutrients for these bodies of water are nonpoint discharges.

Various investigators have evaluated the nutrient contributions from rural areas. These data are presented below and summarized in Table 2. Three frequently quoted works were authored by Sawyer (21), Slyvester (22), and Englebrecht and Morgan (23).

TABLE 2. - Nutrients in Rural Runoff

Land Use	Stream Flow or	Surface Runoff	Nitrogen, lb/acre/yr	Phosphorus, lb/acre/yr	Remarks	Reference
Forest and Grazing Area	X		0.65 NO_3-N 0.90 Total N	0.33 Total P	Little cultivated land, Data extrapolated from 2 months sampling	33
Farmland	X		7.0 Total N	0.4 Total N	General farming conditions	21
Forested	X		1.3-3.0 Total N	0.3-0.8 Total P	Some logging and road construction	22
Diversified Farming		X	2.5-24.0 Total N	0.9-3.9 Total P	Irrigation return flows	22
Farmland	X		-	0-15 Ortho plus Hydrolyzable P_2O_5, as P	Heavily cultivated land. Data extrapolated from 6 summer months	23
Research Plots		X	3.1-6.4 Total N	0.03-0.21 Total	Natural conditions, small plots	10
Farmland		X	8.4 Total N	0.07 Total P	173 acre cultivated site in corn and oats	4
Research Plots and Orchard		X	0.8-237 Total N	0.36-9.0 Total P	Natural conditions, 1.5 acre plots, 5 acre orchard	5

TABLE 2. - (continued)

Land Use	Stream Flow or	Surface Runoff	Nitrogen, lb/acre/yr	Phosphorus, lb/acre/yr	Remarks	Reference
Farmland	X		7.35 NO_3-N	0.05 Ortho and Poly PO_4	No significant point discharges	29
Farmland	X		3.8 Total N	0.24 Total P	20% forest, 80% crop land and pasture	30
Rangeland	X		0.56 NO_3-N	0.021 Soluble P 0.067 Total P	Primarily grazing, no chemicals added	26
Farmland and Pasture		X	3.6 Total N	1.1 Total P	Higher than normal runoff, frozen sample storage	31
Farmland and Pasture	X		4.0 Total N	0.2 Total P	Mostly pasture, 6 mo. data, frozen sample storage	28
Irrigated Field			3.1 Total N	0.07 Total P	Subsurface drainage, no fertilizer applied	27
Research Plots		X	3.9 Total N	1.2 Total P	Small control plots with no applied manure, frozen sample storage	32

Sawyer (21) estimated the nitrogen and phosphorus present in agricultural runoff by sampling streams which did not receive municipal or industrial discharges. The higher nutrient values came from areas which contained marsh lands. Annual contributions of 7 lb/acre/yr of nitrogen and 0.4 lb/acre/yr of total phosphorus were reported. Critical nutrient levels in support of algal blooms were listed at 0.30 ppm for inorganic nitrogen and 0.01 ppm for inorganic phosphorus.

Slyvester reported on nitrogen and phosphorus loads from irrigation surface return flows in the Washington Yakima Valley. Nitrogen values ranged from 2.5 to 24.0 lb/acre/yr and phosphorus varied from 0.9 to 3.9 lb/acre/yr. Also listed were some nutrient values from forested areas which were subject only to some logging and road construction. Based on stream samples, total nitrogen varied from 1.3 to 3.0 lb/acre/yr and total phosphorus ranged from 0.3 to 0.8 lb/acre/yr (22).

Engelbrecht and Morgan estimated the amount of phosphorus related to land drainage by deducting the phosphorus contributed from sewage treatment plant effluents. Samples were collected from the Kaskaskia River in Illinois and reflected phosphorus contributions from six heavily cultivated drainage areas ranging in size from 12 to 5220 square miles. Determinations were made for orthophosphate and hydrolyzable phosphate as P_2O_5. Total phosphorus was not determined but was estimated at 20% to 30% more than the ortho plus hydrolyzable P_2O_5. Reported values of ortho plus hydrolyzable P_2O_5 ranged from 0-15 lb/acre/yr as P (23).

Nutrient losses from small plots in western Minnesota were reported by Holt (10), Holt et al. (24), and Timmons et al. (11). Based on data collected for two years, Holt lists measured values of 3.1 and 6.4 lb/acre/yr of nitrogen and 0.03 to 0.21 lb/acre/yr of phosphorus (10). Timmons et al. extrapolated these data based on soil-loss information for seven years and estimated annual nutrient losses at 31 to 183 lb/acre of nitrogen and 0.85 to 1.1 lb/acre of phosphorus (11). Large quantities of soluble phosphorus were observed in snowmelt runoff from alfalfa plots. This loss of soluble phosphorus was verified by a laboratory investigation conducted by Timmons et al. (25). Alfalfa and bluegrass crops contributed substantial amounts of soluble nutrients.

Recent data can be found from several sources. McCarl measured 0.07 lb/acre/yr of total phosphorus and 8.4 lb/acre/yr total nitrogen from a 173 acre cultivated field in South Dakota (4). Weidner et al. reported annual losses of 0.8 to 237 lb N/acre/yr and 0.36 to 9.0 lb P/acre/yr from two 1.5 acre watersheds and a 5 acre apple orchard in Ohio (5).

A 30,000 acre drainage basin in southwestern Ontario used primarily for summer pasture was the subject of research by Campbell and Webber (26).

Little or no chemicals or fertilizers were used on the land. As expected, low nutrient loads were measured. Annual values of 0.56 lb/acre/yr of NO_3-N, 0.021 lb/acre/yr of soluble phosphorus, and 0.067 lb/acre/yr of total phosphorus were reported.

An indication of the nutrients in subsurface irrigation drainage is apparent from data presented by Johnson et al. (27). The drainage beneath four irrigated fields in the San Joaquin Valley of California was measured. One of the fields did not receive any fertilizer and its drainage contained 3.1 lb N/acre/yr and 0.067 lb P/acre/yr.

The Department of Biological and Agricultural Engineering at North Carolina State University at Raleigh sampled the discharge from Site F, an area draining 75 acres of pasture, corn, and orchard (28). Samples were frozen prior to analysis. Data were not presented to verify the sample preservation method used. Extrapolating six months of data yields results of 4.0 lb/acre/yr of nitrogen and 0.6 lb/acre/yr of phosphate.

Wang and Evans reported on the nutrient observations made in an extensive study of Lake Bloomington in central Illinois (29). The average precipitation and runoff are 36.5 and 9.05 in./yr, respectively. The drainage area did not have any important point discharges. The total annual runoff of nitrate-nitrogen was given as 4700 lb/sq mile and the annual contribution of phosphorus was 32 lb/sq mile.

Waste discharges in the Potomac River Basin were evaluated by Jaworski and Hetling (30). An estimated 5,840 sq miles were in cropland and pasture. This area yielded 0.24 lb/acre/yr of phosphorus and 3.8 lb/acre/yr of nitrogen. The major source of all nutrients was from wastewater. However, agricultural runoff contributed 65% of the nutrients attributed to land runoff although agricultural land represented only 38% of the total area. The remaining area was in forest or urban land.

Personnel from the University of Wisconsin instigated surface runoff studies from both natural watersheds and small research plots (31) (32). Samples were frozen and stored prior to analysis with a Technicon Autoanalyzer at a University of Wisconsin laboratory. Data verifying the preservation method used were not presented.

Surface runoff from natural watersheds of 22.8, 52.5, and 171 acres was sampled by Witzel et al (31). Runoff data for one year, including some snowmelt runoff, were obtained. The smallest site was in pasture, and the remaining sites were in pasture, hayland, and cultivated crops. Commercial fertilizers and animal manures were used. The annual average surface runoff is about 1.75 in. of which 75% results from snowmelt or rainfall on frozen soil. The particular year in question had about twice the average annual runoff and gave nutrient loads of 3.6 lb/acre of nitrogen, 1.1 lb/acre of phosphorus, and 7.6 lb/acre of potassium. Average annual contributions were estimated at 2 lb/acre/yr, 0.6 lb/acre/yr, and 4 lb/acre/yr of nitrogen, phosphorus and potassium, respectively.

Minshall et al. used various manure applications on eight small plots (10 ft by 40 ft) and evaluated the effects of the applications on the quantities of nutrients in the surface runoff (32). Data were collected for three years. Annual nitrogen losses were 11.3 lb/acre for fresh manure applications, 3.59 lb/acre for fermented manure, and 3.20 lb/acre for liquid manure. This was compared to 3.89 lb/acre/yr of nitrogen which was obtained from a control plot which had not received any manure. Annual phosphorus losses were 2.62 lb/acre for fresh manure, 0.72 lb/acre for fermented manure, and 0.86 lb/acre for liquid manure. Phosphorus lost from the control plot was 1.17 lb/acre/yr.

Winter nutrient losses on unmanured plots were found to be less than losses from manured summer plots. These unmanured plots lost more nutrients than the manured plots during the summer, however. They concluded that manure should be spread only on unfrozen ground, and the manure should be incorporated into the soil as soon as possible (32).

Jennelle and Grizzard studied the eutrophication of a Virginia lake. Stream samples were taken at various tributaries and nutrient sources were identified as wastewater discharges, rural runoff, and urban runoff. Rural runoff contributed 710 lb PO_4/day, 456 lb NO_3-N/day, and 176 lb total kjeldahl nitrogen/day. Sampling was for a two month period, and the data shown in Table 2 are extrapolated to an annual basis. They concluded that even if expensive nutrient removal from municipal and industrial discharges was practiced that enough nutrients would still be added to cause rapid eutrophication to continue (33).

BACTERIOLOGICAL INDICATORS

Indicator organisms are usually used to designate the bacteriological quality of a water or wastewater. The bacteriological examinations are important in that they imply the presence or absence of a potential health hazard. Fecal contamination of a water resource is particularly important, especially if the contamination can be attributed to human sources.

In a recent symposium Middaugh et al. discussed the possibilities of using some very selective indicators to distinquish between animal or human fecal pollution. These were indicators such as Streptococcus bovis or certain Salmonella species (34). Some of the procedures appear promising, but additional work remains to be done in unknown areas. One such area is the determination of survival characteristics of Streptococcus bovis after animal discharges reach a surface water.

As early as the mid-1950's investigators recognized the problem of distinguishing between animal and human fecal contamination of water. Cooper and Ramadan studied the physiological and biochemical characteristics of fecal streptococci taken from the feces of humans, bovine animals, and sheep. The isolated organisms were split into six groups. One group represented the typical Streptococcus faecalis group, while the other groups were something other than typical S. faecallis. Their results showed that two of the groups of fecal streptococci were derived entirely from humans, two groups were traced directly to animal sources (over 90%); but that two groups were mixed and were not characteristic of a particular source (35).

Geldrich discussed the use of bacteria as indicators of the sanitary quality of water, and the techniques involved in testing for fecal coliforms (36). He presented data (36) relating the average densities of fecal coliforms and fecal streptococci present in the feces of humans, ducks, sheep, chickens, cows, turkeys, and pigs. He advocated a fecal coliform to fecal streptococcus ratio (FC/FS) to indicate whether contamination was from a human or animal source. A FC/FS ratio less than 0.6 would indicate that the fecal source was non-human.

A FC/FS ratio for a water sample of 1.0 or more is now thought to be a result of human sources, while ratios below 1.0 are thought to result from animal sources. Evans et al. tend to verify this ratio by their study of urban stormwater (37). Nine rainfall runoff events were sampled for total coliform, fecal coliform, and fecal streptococcus organisms from a 27 acre residential district in Cincinnati. Fecal contamination was evident from the biological indicators, although the stormwater source did not have any domestic waste contamination. In seven of the nine samples, the ratio of fecal coliforms to fecal streptococcus was less than 0.84.

Several investigators have attempted to determine the bacteriological quality of rural areas by sampling streams which drained areas devoid of municipal or industrial point discharges (38) (39) (40) (41). Investigations of this nature are intended to define the pollutional load from non-point discharges. Ground water which would enter the stream was not considered separately.

Walter and Bottman collected weekly samples from two watersheds in a recreational area in Montana to determine concentrations of coliform and enterococcus organisms (38). One watershed, with its reservoir, was open to public recreational activities while the other watershed had been closed to the public since 1920. Common recreational activities practiced on the open watershed were swimming, boating, camping, and fishing. Coliform counts increased as the summer progressed, and enterococci counts increased as the water flowed downstream from the reservoirs. Coliform counts from the closed watershed were greater than those from the open watershed in 74% of the tests. Similar results were obtained for enterococci organisms in 59% of the tests. Animals were thought to have been nearer the water in the area closed to the public, and this proximity was offered as a reason for higher counts from the closed watershed. No actual animal counts were made in either area.

Runoff from a 0.75 sq km watershed in Vermont was sampled by Kunkle for two years (39). The watershed had 37% of its area in hayfields, 38% in pasture and 25% in forested land. About 150 head of cattle were grazed at the headwaters of the watershed during the first year, but they were not on the site after the spring of the second year. Samples were obtained from a stream just below the watershed during normal runoff as well as when storm water runoff was occurring. Much of the annual runoff resulted from spring snowmelt, but data were reported only for rainstorms.

During periods of storm runoff, total coliform and fecal coliform densities would rise. Maximum densities of 50 or more times the non-storm runoff levels were obtained. Seven summer storms showed median total coliform concentrations from 5,500 to 80,000/100 ml and median fecal coliform levels of 1,100 to 14,000/100 ml. Over 90% of the storm runoff observations for both total and fecal coliforms were greater than acceptable criteria for swimming waters. Kunkle concluded that fecal coliforms were the better indicator of pollution in his study (39).

Kunkle has also sampled some mountain streams for bacteria in conjunction with Meiman (40) (41). One study obtained counts on fecal coliform, total coliform, and fecal streptococcus bacteria from 604 samples taken at ten stations in the Colorado Rocky Mountains (40). The other investigation recorded bacterial densities for the same indicators from two sites on a mountain stream located 1.5 miles apart. A total of 3,102 observations were made in this later study (41).

Both studies revealed fluctuations in numbers of bacterial indicators. Total coliforms varied from 9 to 300 colonies/100 ml, fecal coliform and fecal streptococcus values normally ranged from 0-75 colonies/100 ml, and FC and FS densities would increase to several hundred per 100 ml during extreme flooding. The fecal coliform organisms were found to be most sensitive for detecting animal fecal contamination. Fecal coliform to fecal streptococcus ratios greater than one were obtained from locations below cattle grazing areas. The fecal streptococcus organisms were thought to be drastically affected by the cold water temperatures involved in the studies (40) (41).

A study to estimate the contribution of agriculture and/or urban runoff to part of a northern lake was undertaken by Claudon et al. (42). The work was done on Lake Mendota near Madison, Wisconsin. The major sources of organisms were from a residential storm sewer and a wash-water drain at the University of Wisconsin Experimental Farm. They found 27 of 53 samples to be positive for Salmonella. They concluded that runoff, even diluted runoff, can regularly add Salmonella to a recreational lake.

Published results of only three investigations were found which examined natural surface drainage from agricultural lands before the runoff enter a watercourse. Two of these investigations were conducted on a 173 acre watershed near Brookings, S. Dak. Benson (3) sampled the watershed during one storm in 1969, and McCarl (4) sampled the same watershed during the 1970 season. Benson obtained samples for total coliform, fecal coliform, and fecal streptococcus throughout a rainfall runoff event. Densities of the organisms generally varied with the flow for the first quarter of the event, but random densities were obtained throughout the remainder of the event (3).

McCarl obtained microbial densities for total coliform, fecal coliform, and fecal streptococcus organisms for seven runoff events in 1970 (4). Six of the runoff events resulted from rainfall, but one was a snowmelt runoff event which occurred between rainfall events. McCarl concluded that the concentrations of the organisms generally varied with the suspended solids and organic matter present in the runoff. Analysis of the fecal coliform to fecal streptococcus ratio led him to believe that animals rather than humans were the source of the fecal pollution. Manure had previously been spread on the drainage basin.

Results of the runoff from six watersheds near Coshocton, Ohio, were reported by Weidner et al. (5). One watershed contained 303 acres, three had 1.5 acres each, and two were sized at 7.5 acres each. The 303 acre basin had mixed cover, and two of the 1.5 acre sites were in a 4-year rotation of corn, wheat, and meadow. One of the 7.5 acre watersheds was strip-cropped, and the other was not. The remaining 1.5 acre watershed was used to study special pesticide applications and mulch planting techniques.

The researchers determined the densities of total coliform, fecal coliform, and fecal streptococcus organisms in the runoff from five watersheds. For some of the watersheds, 90% of the samples exceeded 1000 total coliforms per 100 ml; and this figure was exceeded in 50% of the samples from all of the watersheds. Densities of fecal streptococci were greater than fecal coliform organism densities so they concluded that ". . .pollution is from animals rather than humans, as one would expect" (5).

PESTICIDES

The production and use of pesticides has grown throughout the United States and the world. During the period from 1963 to 1967, for example, the United States production of synthetic organic pesticides increased by more than 37 percent. The synthetic organic pesticides include almost all of the known pesticides (43).

Agriculture has continued a large demand for pesticides, particularly for corn crops. In a recent year, 57% of the corn planted in the United States was treated with herbicides, and 33% with insecticides. Sometimes large areas are treated from the air, but weather and other practical considerations occasionally limit this method (43).

The personnel at the Southeast Water Laboratory of the U. S. Environmental Protection Agency in Athens, Georgia have intensively studied insecticide runoff from agricultural land. Nicholson, Grzenda, and others have reported this work in several journals and at various meetings (44) (45) (46) (47) (48) (49).

Nicholson lists three main problems that must be considered when relating pesticides to water quality. The first problem stems from very high pesticide concentrations which result in fish kills or other aquatic damage. The second problem is the outcome of exposing aquatic life to low-level, long-term dosages of pesticides; and the third problem results when pesticides are processed through municipal water treatment facilities. Land runoff is a prime source of the entry of pesticides into surface water resources (47).

At a recent conference, Nicholson expressed the public's concern over pesticides. The focal point of this concern has become DDT. Several countries have banned the use of DDT, and Hungary has banned all organochlorine insecticides (45).

Nicholson and his co-workers showed that several insecticides can enter a watercourse in conjunction with runoff water. He discussed two fish kills which occurred and mentioned instances where fish-eating birds have been poisoned. This poisoning was thought to have occurred from the biological magnification process (46).

Greichus also traced the build-up of pesticides in the food chain by examining the fat of different South Dakota fish, birds, and animals. The various pathways of insecticide residues in an aquatic environment were discussed, and data regarding the concentrations of insecticides in the Lake Poinsett ecosystem were present (50).

Weibel et al. collected rainfall and runoff samples at some watersheds near Coshocton, Ohio. Specific examples of rainfall transmitting pesticides were documented. In one storm, chlordane, heptachlor epoxide, DDE, DDT, dieldrin, and 2,4,5-T were all detected. Runoff water from a field of winter wheat contained 0.43 μg/l of organic chlorine. The concentration of organic chlorine gives an estimate of the pesticide concentration because a large number of pesticides contain organic chlorine (51).

The fate of agricultural chemicals after they are applied to the land is an important consideration in regard to the quality of agricultural surface runoff. If chemicals are loosely held by the soil, they could be leached into the groundwater or dissolved into surface runoff. If they are tightly held by the soil particles, soil losses become doubly important.

Several researchers have investigated pesticides in the soil environment (52) (53) (54) (55) (56). Lichtenstein stated that some insecticides such as aldrin and parathion are tightly attached to soil particles and that only small amounts may be removed by water. He recognized that surface waters could become contaminated from insecticides being adsorbed by the soil and subsequently being washed from the field by runoff water (52).

McCarty and King correlated the extent of pesticide adsorption with the clay content of the soil used. They found that the rate of movement of a pesticide in the soil was inversely related to the amount of adsorption (53). The actual method of clay adsorption and the factors affecting this adsorption became topics for research by several investigators. White and Mortland discussed clay-organic interactions and decided that the soil minerals most responsible for adsorption were those found in clay, and that the attraction of the organic cations to the clay was proportional to their molecular weight. They listed several mechanisms for bonding, and said that the clay particles were active because of their small particle size and relatively large specific surface (54).

Huang and Liao (55) also studied clay mineral adsorption of pesticides, and they present a wealth of data regarding individual pesticide adsorption rates with various adsorption media. They disagree with White and Mortland, however, as they state that the ". . .adsorptive capacities of the clay minerals are not correlated to their ion exchange capacities or specific surface areas".

Bailey et al. (56) also studied the adsorption mechanisms of a clay, montmorillonite. They stressed that the pH of the clay system plays an important role in the adsorption process. Adsorption mechanisms for both basic and acidic organic compounds were given.

Actual data concerning the level of pesticides in streams are important to a runoff study particularly if the streams drain predominantly agricultural areas. Several investigators have reported field information from some stream studies.

One of the problems previously mentioned by Nicholson dealt with pesticides being passed through municipal water treatment facilities (47). A four-year field study where this problem occurred was reported by Thoman and Nicholson (48). The Flint Creek watershed of Alabama drains a 400 square mile cotton farming area. Agriculture is the basic industry and cotton is the principal crop. Toxaphene, BHC, and DDT were the most commonly used insecticides in the basin. Insecticides were not applied from the air to any extent.

Just below the watershed, a town of 7,000 people drew its water for the community. An extensive sampling program revealed that toxaphene and BHC were present in both the raw and finished water throughout each year of the study. DDT was not recovered. The lack of DDT in the water was attributed to ". . .its strong affinity for organic matter in the soil, and to its extreme insolubility in water" (48).

Grzenda et al. reported on stream samples taken from a mountain stream which carried the runoff from a 4,000 acre hardwood forest in North Carolina. DDT was sprayed by airplane in 1961 to halt an infestation of a hardwood defoliating insect, Ennomos subsignarius. DDT residues were detected in the stream and ranged from 0.346 to 0.005 ppb. Controlled spot-applications were practiced the following year on 49% of the basin after which DDT residues were not detected in either stream or sediment samples (49).

Endrin is often used in sugar cane production. Numerous fish kills in Louisiana were attributed to endrin without substantiating data. Consequently, Lauer et al. studied the surface waters to determine if the charges were justified. Endrin was recovered from all the streams sampled and surface runoff was listed as the main source of endrin. Heaviest recoveries were reported during the first runoff event after an endrin application (57).

Data from a survey of 3 of the Great Lakes and 56 major drainage basins of the United States were discussed by Nicholson (45) and Hill (44). The original data for the discussion were obtained in 1964 by Weaver et al. (58). The widespread distribution of dieldrin, endrin, DDT and DDE was noted. However, concentrations of all pesticides in water were less than 1 ppb. Additional stream surveys since then have verified these results (45).

The literature pertaining to pesticides seems to indicate that they are widespread in the environment, being spread by water, soil, and air. Most existing data were obtained from stream samples, although the personnel at the Southeast Water Laboratory have insecticide information for agricultural runoff. Weibel et al. also related pesticides to some organic chlorine measurements from some small watersheds near Coshocton, Ohio (51). Data regarding pesticide levels in agricultural runoff waters for the upper mid-west were not found.

SECTION V

RESEARCH SITES

INTRODUCTION

When this research to quantify the pollutants in agricultural runoff was first proposed, the plan of operation was to determine concentration of pollutants in the runoff from drainage basins selected from studies initiated by the South Dakota Department of Highways and the U. S. Geological Survey. A total of 80 small drainage basins, with areas from 0.5 to 10.5 square miles, were to be instrumented with digital stage and rainfall recorders for determining the rainfall-runoff relationships. Consequently, measurements of flow and precipitation collected with the digital recorders could have been utilized. Several objections to this plan were foreseen. Travel distances to maintain automatic samplers and collect samples might have been excessive. Compositing of samples without readily available flow data would be difficult. The drainage areas would be large and probably include numerous cropping practices and soil types. For these reasons, the decision was made with the advice of FWPCA personnel to select smaller drainage areas and to utilize flow measuring and sampling equipment provided within the project.

The starting date for the project was proposed initially as July 1, 1969. Delays to November 1, 1969 were recognized as acceptable to allow selection and instrumentation of the drainage basins for study during the following spring and summer runoff season. The initial notification of the approval of the project was received in December 1969 and the project was actually initiated in February 1970. The later-than-planned starting date necessitated selection of drainage areas and sampling sites during the winter when the area was covered with snow.

Because of winter conditions, roadside sites with culverts were selected as study sites to avoid the earth moving that might be necessary for installing the flow measuring equipment. When selecting the study sites for this research, the ideal drainage area was considered to possess the following characteristics:

1. Relatively uniform and well-defined soil type,
2. Farmed uniformly with one crop cover annually,

3. Located near South Dakota State University to avoid excessive travel,
4. Adjacent to an all-weather road,
5. Have a known history of previous land use including applications of pesticides,
6. Have a drainage culvert that would lend itself to installation of flow measuring equipment.

Seven sites were selected. Four of the sites were located during January of 1970 and the remaining sites were selected later in the summer. Figure 1 shows the general location of the sites which are all located in Brookings County, and are within 20 miles of Brookings, S. Dak.

The chosen sites generally follow the criteria of the ideal site. They all have one crop cover and drain to a single point. The approach roads were not ideal, but did allow sampling as necessary. Fertilizer information was obtained from the land operators.

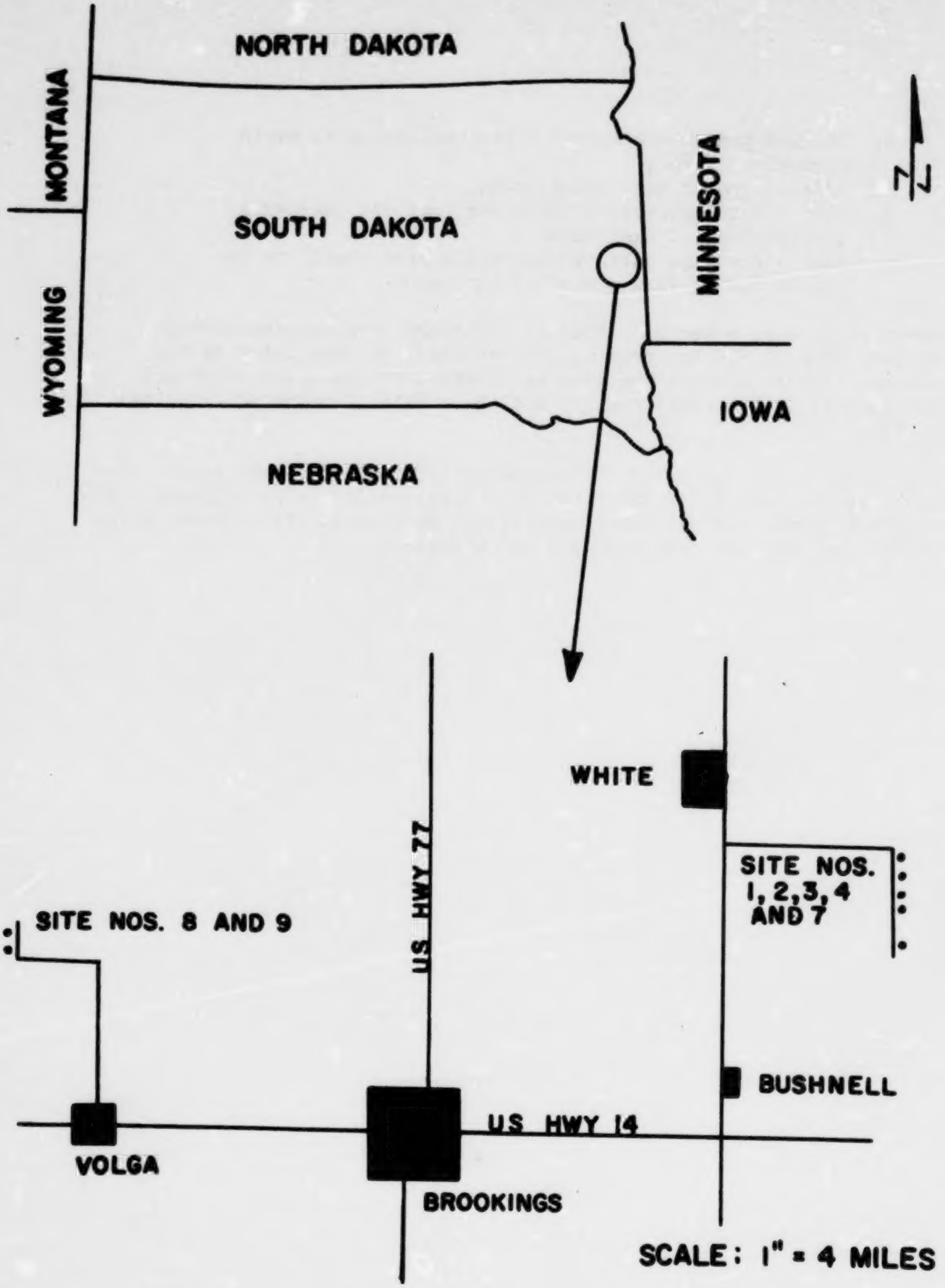
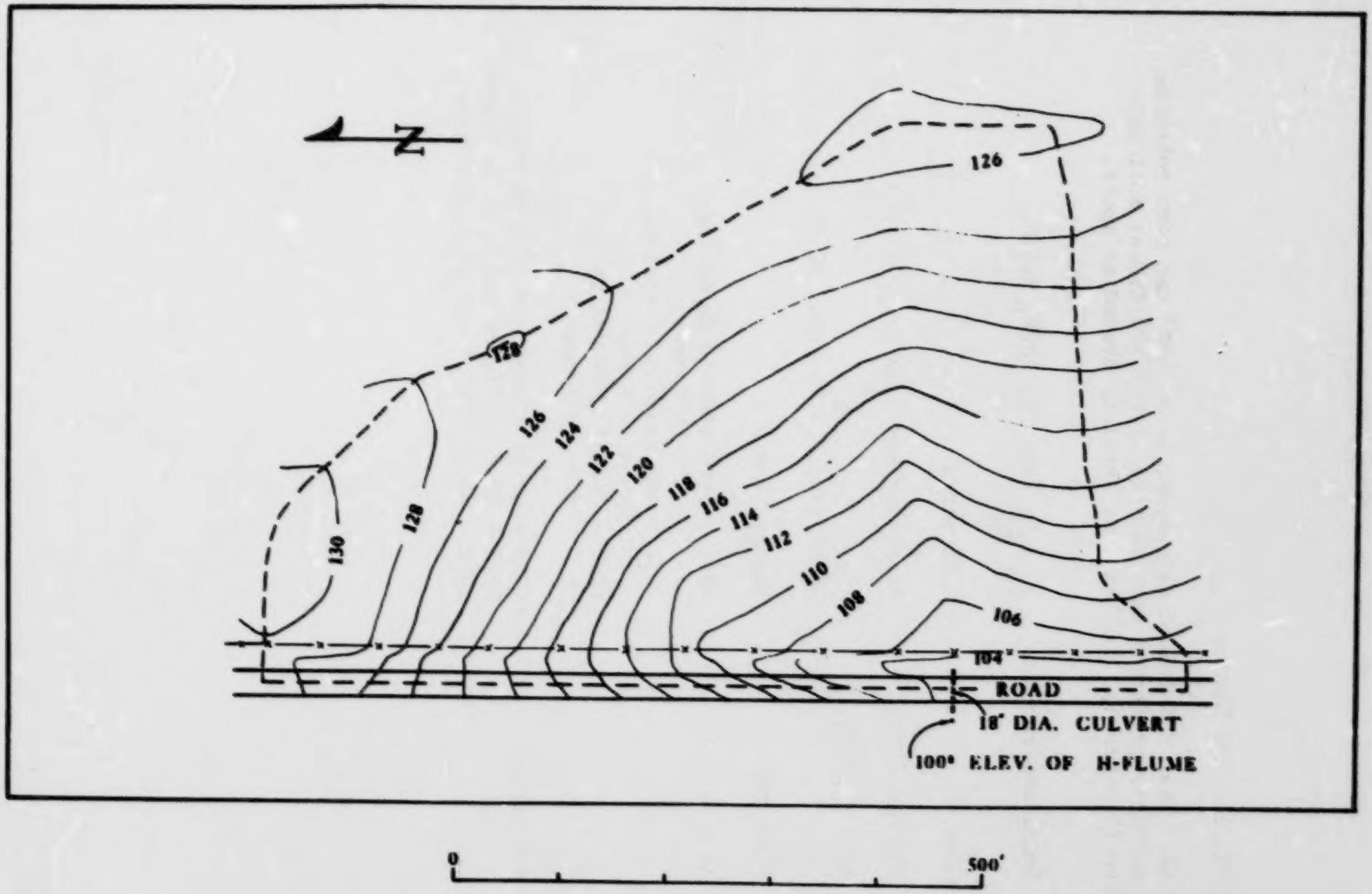

NORTH DAKOTA
MONTANA
SOUTH DAKOTA
MINNESOTA
WYOMING
IOWA
NEBRASKA
N
WHITE
US HWY 77
SITE NOS. 1, 2, 3, 4 AND 7
SITE NOS. 8 AND 9
BUSHNELL
US HWY 14
VOLGA
BROOKINGS
SCALE: 1" = 4 MILES

FIGURE 1. – GENERAL SITE LOCATIONS

SITE NO. 1 (See Figure 2)

Site No. 1 was cultivated and seeded in an oats and corn rotation. The landowner preferred oats because of the additional soil protection it offered. The land was severely eroded in spots.

Legal Description:	NW 1/4, Sec. 23, R48W, T111N, 5th PM
Area:	7.18 acres
Average Slope:	Approximately 4.7%
Soil Texture:	Sandy clay loam 48.8% sand, 24.7% silt, 26.5% clay
Soil Type:	Vienna Loam
Crop Cover:	1970 - Corn stubble in spring, oats in summer 1971 - Oat stubble in spring, oats in summer 1972 - Plowed previous fall, corn in summer
Fertilizer:	1970 - 40 lb N/acre and 26.4 lb P/acre 1971 - 52.2 lb N/acre and 11.5 lb P/acre 1972 - 60 lb N/acre and 26.4 lb P/acre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ROAD
18" DIA. CULVERT
100' ELEV. OF H-FLUME
0
500'

FIGURE 2. - SITE 1

SITE NO. 2 (See Figure 3)

Site No. 2 is adjacent to Site No. 1, and both sites are contained within the same larger area. Consequently, the crop rotation and the fertilizer application was always the same for each site.

Legal Description:	NW1/4, Sec. 23, R48W, T111N, 5th PM
Area:	8.77 acres
Average Slope:	Approximately 4.1%
Soil Texture:	Sandy clay loam 47.8% sand, 24.7% silt, 27.5% clay
Soil Type:	Vienna Loam
Crop Cover:	1970 - Corn stubble in spring, oats in summer 1971 - Oat stubble in spring, oats in summer 1972 - Plowed previous fall, corn in summer
Fertilizer:	1970 - 40 lb N/acre and 26.4 lb P/acre 1971 - 52.2 lb N/acre and 11.5 lb P/acre 1972 - 60 lb N/acre and 26.4 lb P/acre

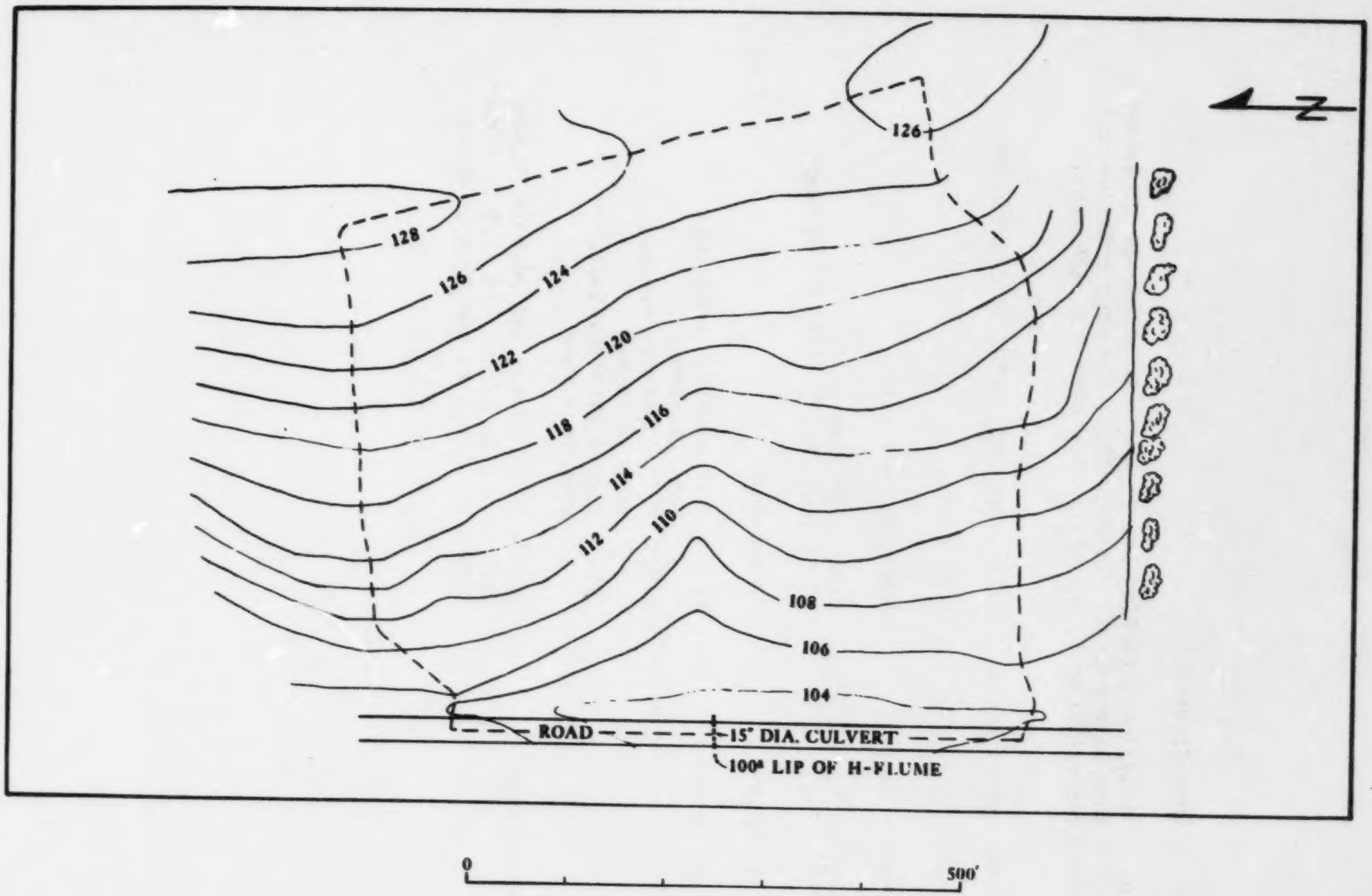
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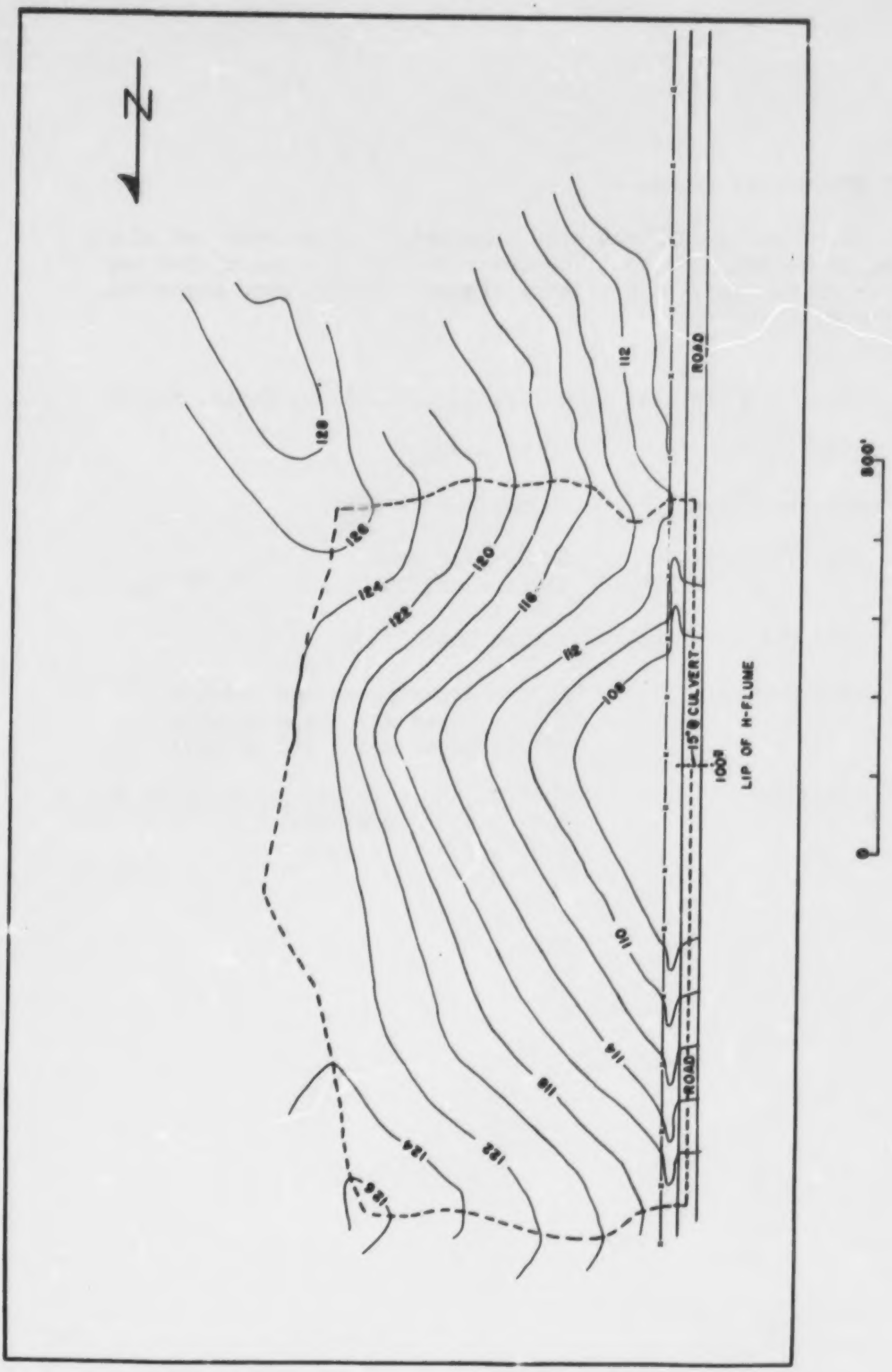
FIGURE 3.- SITE 2

SITE NO. 3 (See Figure 4)

Site No. 3 was a hayfield with a permanent grass cover of mixed brome grass and alfalfa. The cover was cut and put up for hay two or three times each growing season. Cattle were sometimes pastured in the fall.

Legal Description:	SW1/4, Sec. 23, R48W, T111N, 5th PM
Area:	10.12 acres
Average Slope:	Approximately 4.0%
Soil Texture:	Sandy clay loam 46.8% sand, 26.7% silt, 26.5% clay
Soil Type:	Vienna Loam
Crop cover:	1970 - Brome grass and alfalfa 1971 - Brome grass and alfalfa 1972 - Brome grass and alfalfa
Fertilizer:	1970 - 100 lb N/acre and 13.2 lb P/acre 1971 - 91.5 lb N/acre 1972 - 250 lb N/acre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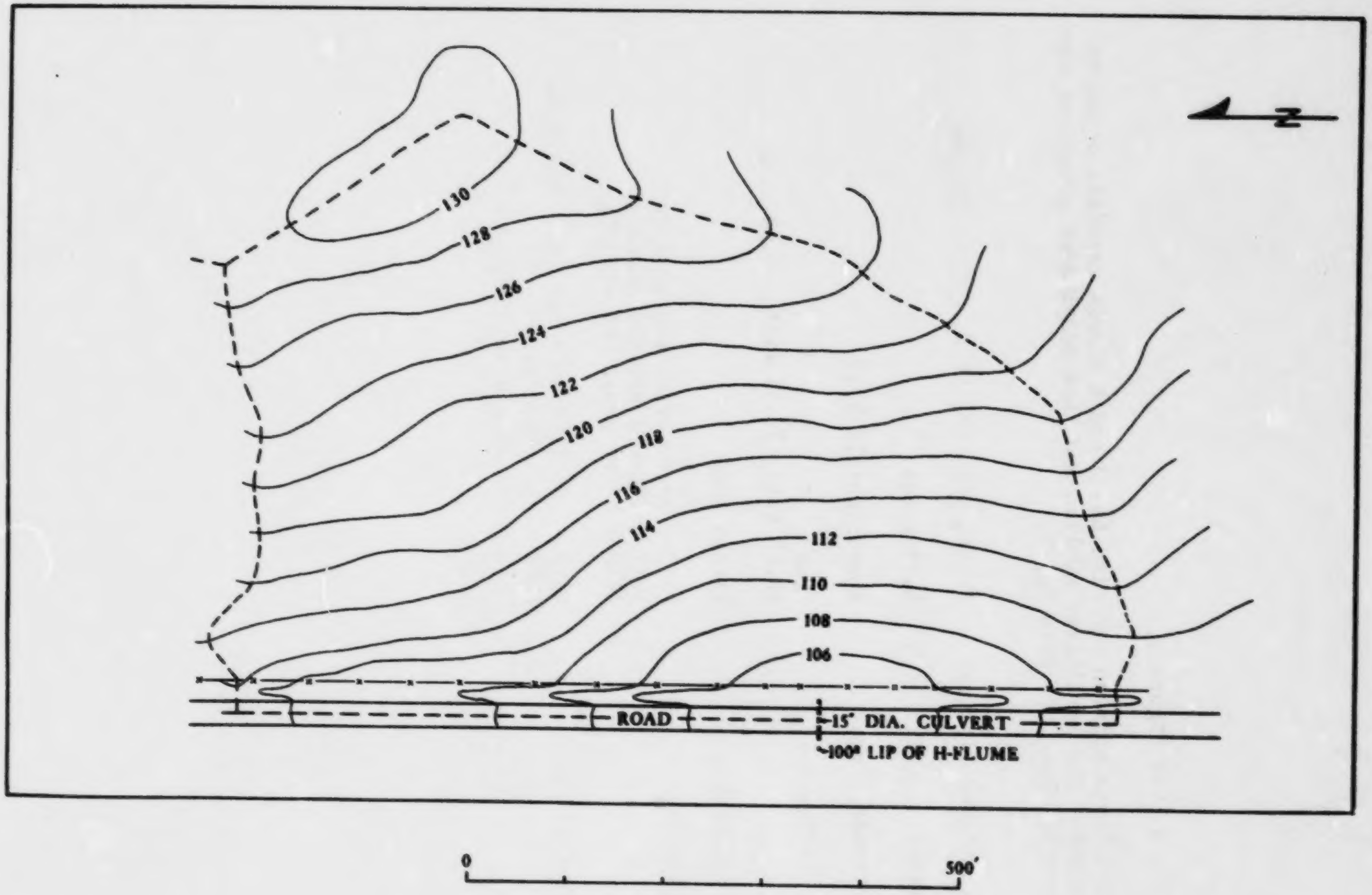
200'

FIGURE 4.—SITE 3

SITE NO. 4 (See Figure 5)

Site No. 4 was adjacent to Site No. 3 and a single hayfield contained both sites. The fertilizer applied and land management practices were the same as those for Site No. 3.

Legal Description:	SW1/4, Sec. 23, R48W, T111N, 5th PM
Area:	8.77 acres
Average Slope:	Approximately 4.1%
Soil Texture:	Loam 48.8% sand, 36.7% silt, 14.5% clay
Soil Type:	Vienna Loam
Crop Cover:	1970 - Brome grass and alfalfa 1971 - Brome grass and alfalfa 1972 - Brome grass and alfalfa
Fertilizer:	1970 - 100 lb N/acre and 13.2 lb P/acre 1971 - 91.5 lb N/acre 1972 - 250 lb N/acre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15' DIA. CULVERT
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FIGURE 5. - SITE 4

SITE NO. 7 (See Figure 6)

Site No. 7 served as summer pasture for a livestock feeder. The pasture was left vacant until mid-summer when it would be heavily pastured for 3 to 4 weeks. The cattle were then removed to another location.

Legal Description:	NW1/4, Sec. 26, R48W, T111N, 5th PM
Area:	15.51 acres
Average Slope:	Approximately 5.4%
Soil Texture:	Sandy clay loam 49.8% sand, 26.7% silt, 23.5% clay
Soil Type:	Vienna Loam
Crop Cover:	1970 - Grazed pasture 1971 - Grazed pasture 1972 - Grazed pasture
Fertilizer:	None

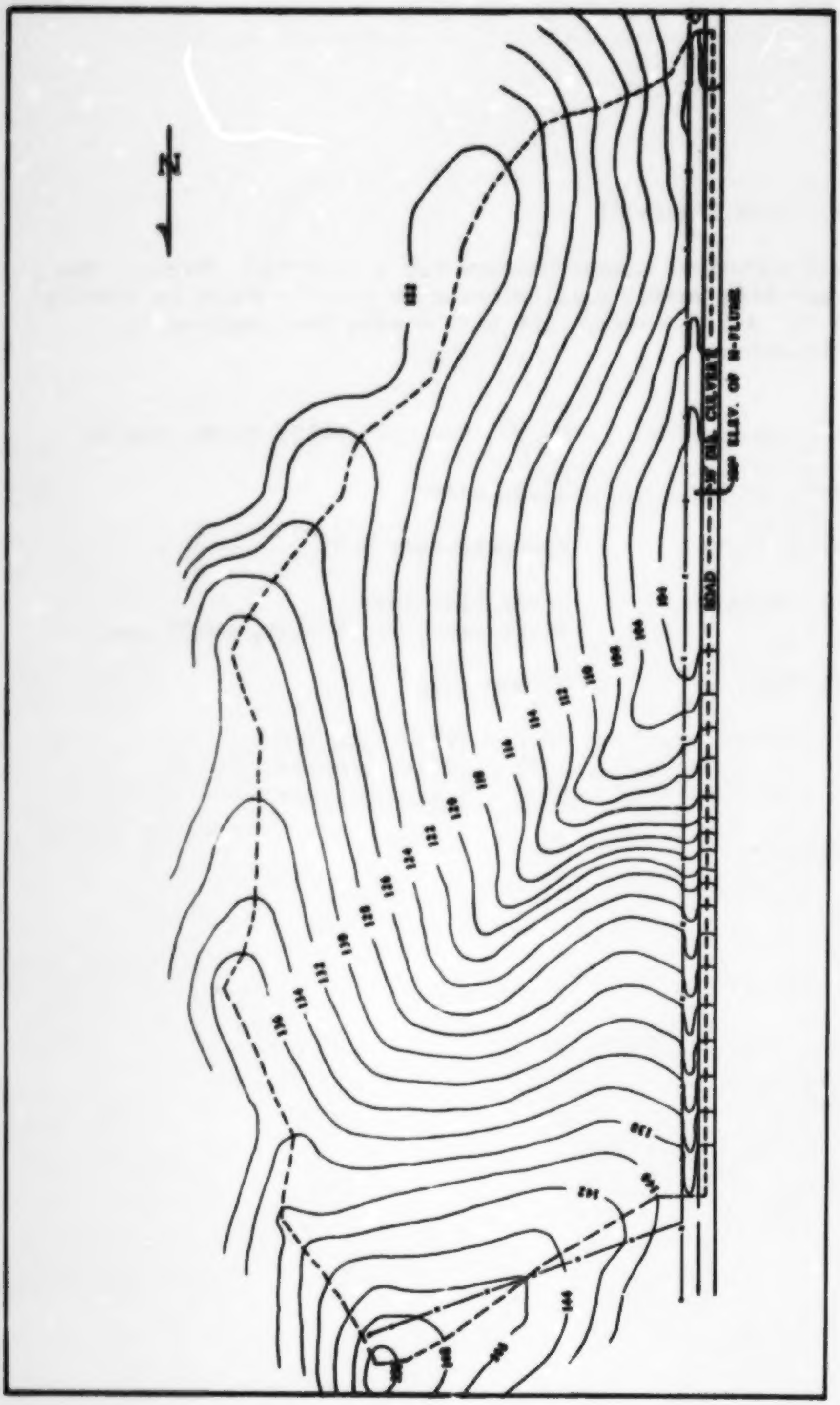
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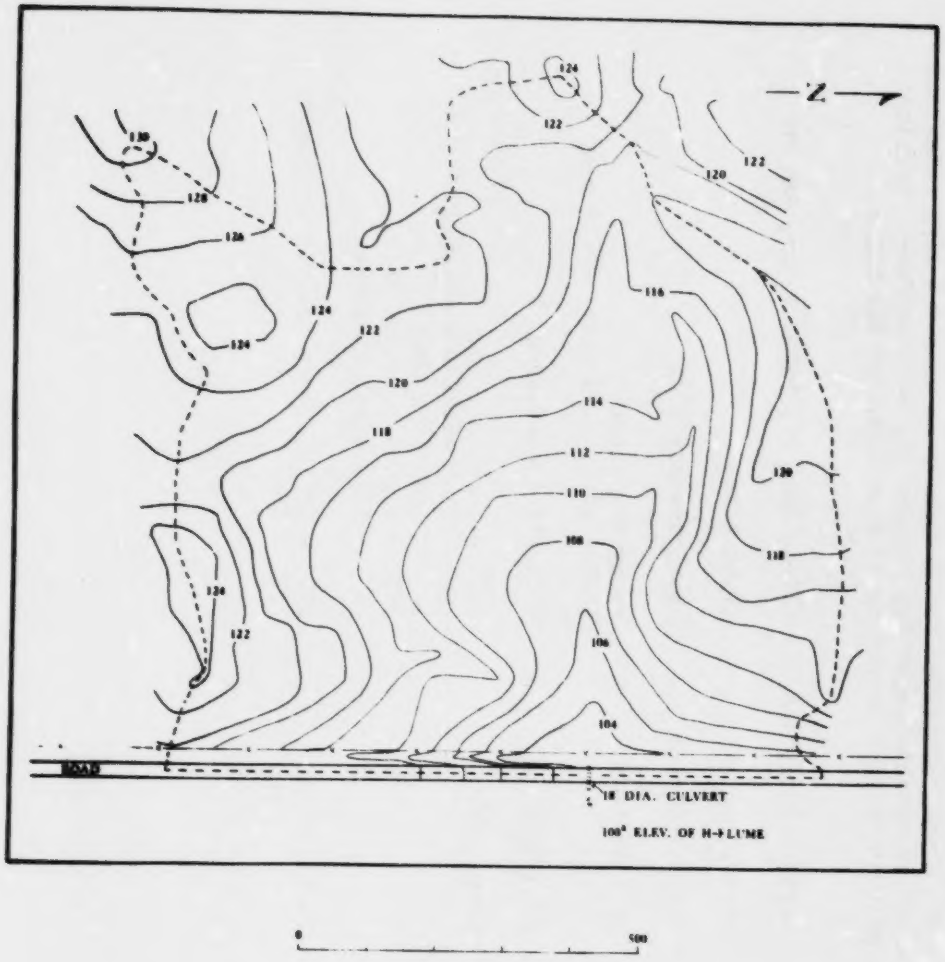
FIGURE 6. - SITE 7

SITE NO. 8 (See Figure 7)

Site No. 8 was cultivated and seeded in an oats and corn rotation. A fairly impervious layer lay beneath the soil surface. Erosion was most noticeable at the upper elevations of the basin.

Legal Description:	SE1/4, Sec. 29, R51W, T111N, 5th PM
Area:	18.68 acres
Average Slope:	Approximately 3.0%
Soil Texture:	Sandy clay loam 46.8% sand, 26.7% silt, 26.5% clay
Soil Type:	Poinsett-Buse-Pierce
Crop Cover:	1970 - Corn in summer 1971 - Corn stubble in spring oats in summer 1972 - Plowed previous fall, idle acres in summer
Fertilizer:	1971 - 29 lb N/acre and 6.2 lb P/acre 1972 - None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100' ELEV. OF H-FLUME
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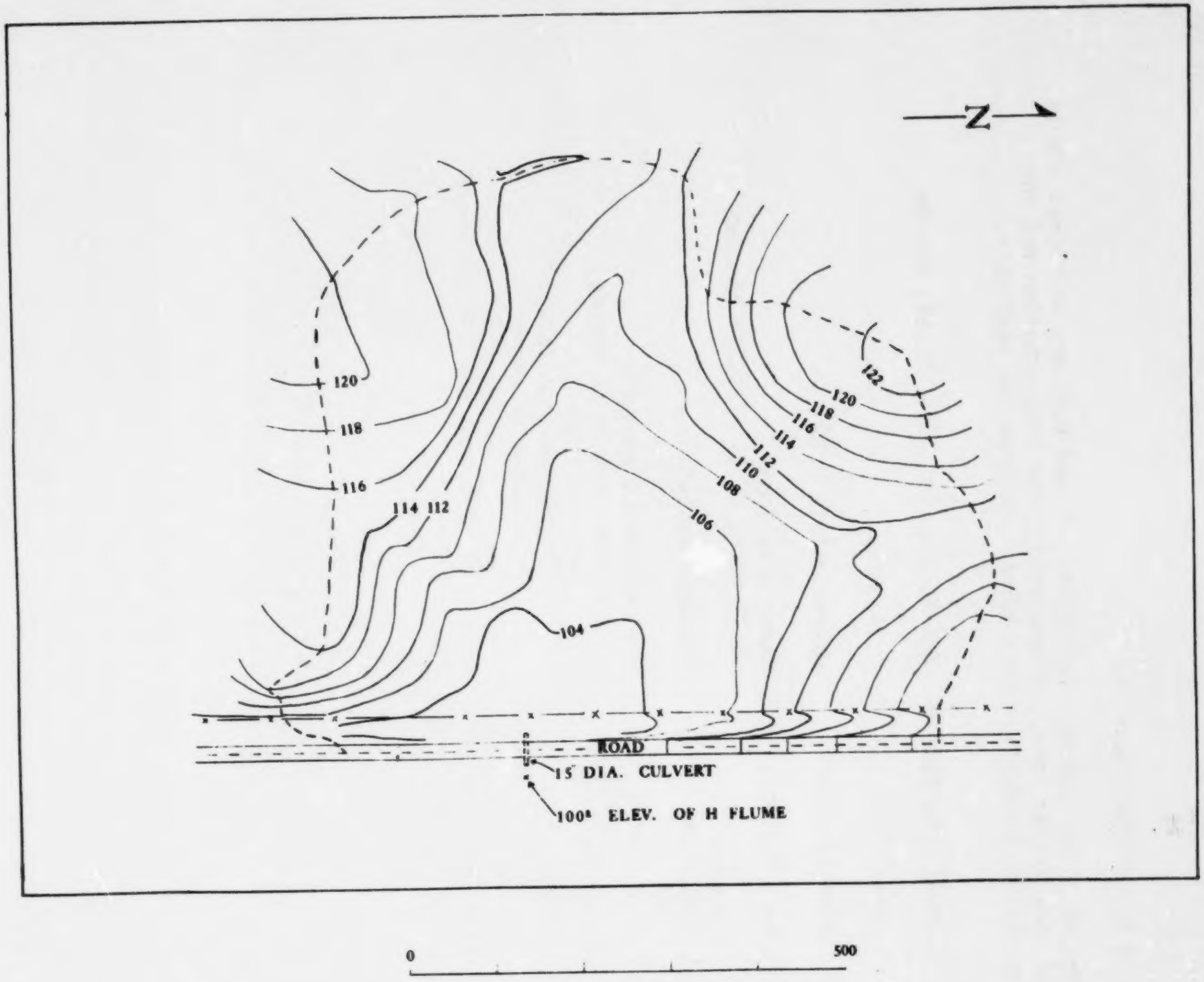
FIGURE 7- SITE 8

SITE NO. 9 (See Figure 8)

Site No. 9 is adjacent to Site No. 8, and both are contained within the same larger area. Consequently, the crop rotation and the fertilizer application were always the same for each site.

Legal Description:	NE1/4, Sec. 29, R51W, T111N, 5th PM
Area:	9.79 acres
Average Slope:	Approximately 2.7%
Soil Texture:	Sandy clay loam 49.8% sand, 25.7% silt, 24.5% clay
Soil Type:	Poinsett-Buse-Pierce
Crop Cover:	1970 - Corn in summer 1971 - Corn stubble in spring, oats in summer 1972 - Plowed previous fall, idle acres in summer
Fertilizer:	1971 - 29 lb N/acre and 6.2 lb P/acre 1972 - None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ROAD
15" DIA. CULVERT
100' ELEV. OF H FLUME
0
500

FIGURE 8. - SITE 9

SECTION VI

FIELD METHODS

SITE INSTRUMENTATION

Flow measuring equipment, water level recorders, and automatic samplers were placed at each site. Figures 9 and 10 show front and side views of the field installation. The drainage from each site passed through a culvert and the installation of the field equipment was on the downstream side of the culvert. All equipment shown was in the road ditch within the right-of-way.

The flow measuring device was an H flume constructed of 14 gauge galvanized steel with a black iron supporting frame. The flume was mounted on a plywood headboard which extended approximately 20 in. underground to eliminate the possibility of water flowing beneath the measuring flume. The flume and headboard were bolted to the sideboards, and the joints were caulked to prevent leakage.

Sideboards were extended beyond the culvert exit for a distance of at least five times the height of the measuring flume. This was in accordance with installation instructions given in Field Manual for Research in Agricultural Hydrology (59) to avoid velocity disturbances upstream from the flow measuring device. The distance between the sideboards was equal to the flume width. Sideboards were 4 ft by 8 ft sheets of exterior plywood and extended a minimum of 15 in. below the ground surface to eliminate leakage during runoff events.

Sites No. 1, 2, 3, and 4 were equipped with a 1.5 H flume; while Sites No. 7, 8, and 9 were provided with a 2.5 H flume. Dimensions and rating tables for the flumes are listed in "Agricultural Handbook No. 224" (59).

A Leupold Stevens Type F water level recorder was used to measure the depth of flow in the flume during rainfall runoff events. A continuous record of the depth was traced on a graph by the recorder. The depths were later converted to flow measurements using the rating table previously mentioned. The recorder was equipped with a self-starting device which actuated when the depth of flow through the flume reached 0.05 ft.

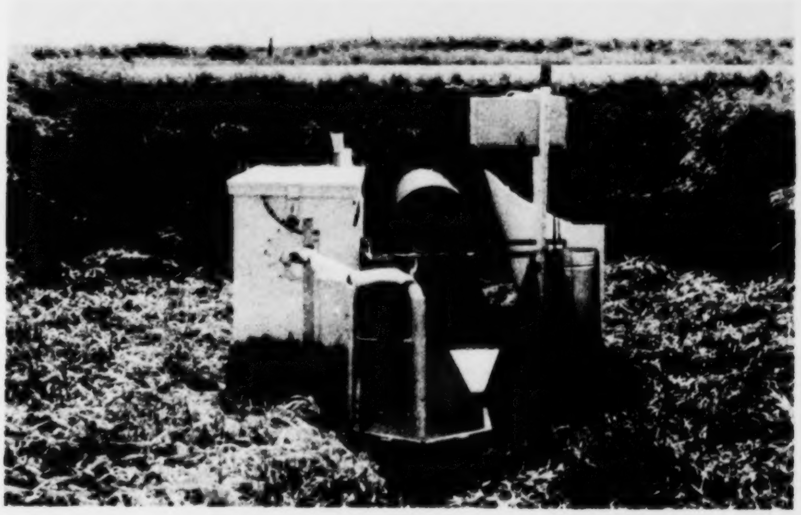


FIGURE 9. - Front view of field installation.

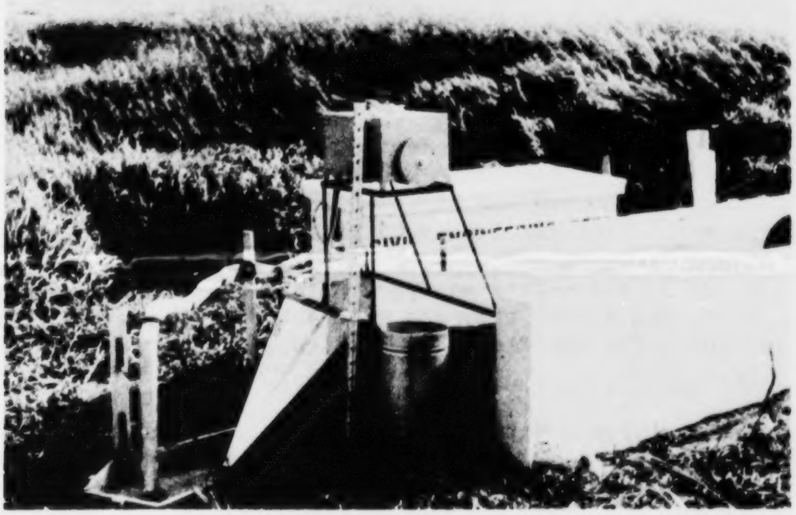


FIGURE 10. - Side view of field installation.

During spring snowmelt, the water in the recorder's stilling well was prone to freeze even though the water was still flowing freely in the culvert and flume. Consequently, spring snowmelt runoff measurements were obtained manually using a staff gauge. The recorder was used for rainfall events only.

As flow would commence from the culvert and proceed through the flume, the float would start to rise in the stilling well. The movement of the float actuated the self-starting mechanism which started the recorder. The recorder was modified to send a signal to the automatic sampler at predetermined time intervals. The sampler utilized a vacuum principle to obtain a runoff sample each time a signal was received.

A wooden catch-basin was designed and fabricated to assist in obtaining representative samples when using the automatic sampler. The catch-basin would intercept about one-half of the flow, and allow mixing to occur as the sample was being taken. The automatic sampler head was located 1 1/4 in. above the floor of the catch-basin. A drainage notch in the front of the catch-basin assisted in sample collection by retarding the runoff water at low flows. The notch and catch-basin were fashioned to maintain a self-cleansing unit, however. Figure 10 shows the positioning of the sampler head and the catch-basin. Verification of the sampling equipment was accomplished by obtaining samples at both the catch-basin and the culvert outlet. Solids determinations conducted on the analogous samples were used for comparison.

Plastic rain gages which could measure rainfall of up to 6 in. were placed at Sites No. 1, 4, 7, and 9. These plastic rain gages were manufactured by Edwards Manufacturing Co. of Albert Lea, Minnesota. Sites No. 2 and 8 were equipped with a recording rain gage which recorded precipitation with respect to time. Rainfall intensity could then be calculated. The recording rain gages were manufactured by the Bedford Instrument Co. of Baltimore, Maryland. These recording or weighing rain gages are of U. S. Weather Bureau approved design with an 8 in. diameter opening. They also had the capability of measuring rainfall of 6 in. or less.

SAMPLING SNOWMELT RUNOFF

Samples of snowmelt runoff were taken manually from each site at periodic intervals throughout each day. On a normal day, about five or six samples were taken from each site. More frequent sampling was deemed unnecessary because of the relatively uniform qualities of the runoff.

Each time that sampling occurred, two individual samples were collected. One sample was obtained in a sterile plastic bag for bacteriological testing. Another sample was obtained in a clean glass container.

All samples were marked for identification. Two composite samples were made after the day's sampling was completed; one from the plastic bags and one from the glass containers.

Depth measurements were taken from the H flumes throughout each runoff day. Usually depths were measured and recorded at one-half hour intervals from about 8 AM to 6 PM. Readings were taken at less frequent intervals thereafter, since the flow would normally have diminished by this time. Readings were taken with a staff gage and recorded to the nearest one-hundredth of a foot.

SAMPLING RAINFALL RUNOFF

Because of the short duration and unpredictable occurrence of a summer rainstorm, it was not possible to collect these runoff samples manually. An automatic sampler was therefore used to obtain rainfall runoff samples. Manual sampling was sometimes employed to supplement those samples collected by the automatic sampler. Manual sampling was especially necessary for those rainfall events which had a duration of more than four hours.

Desirable criteria developed for the automatic sampler for the project included that it be self-starting, obtain a large volume sample, and collect representative samples of the total flow. The self-starting feature was necessary because the research sites were remotely located and personnel were unavailable at short notice to collect samples. A sample volume in excess of 1,500 ml was needed for the laboratory determinations. Because of the anticipated quality changes that would occur throughout a runoff event, it was necessary that the final composited sample depict the entire runoff period. Also since electrical power was not available at the remote locations, any sampler which needed an electrical hook-up was unsuitable.

A satisfactory sampler to meet these criteria could not be purchased. Many of the commercial samplers required 110 volt electrical energy to drive a sampling pump. Other samplers obtained a composite sample comprised of individual aliquots collected at fixed time intervals and because the volume of each individual aliquot was the same, the composite sample would not be representative of the runoff event. Still other samplers could not be adapted to become self-starting when flow began. Because of these shortcomings, an automatic, self-starting sampler was designed to satisfy the requirements of the project.

The sampling unit designed for this project incorporated the flow measuring device, an H flume equipped with a water level recorder, as an integral part of the sampling unit. Flow through the flume started the sampling sequence.

The sampler contained 12 sample bottles (about 2 liters each) which had been evacuated. As the vacuum was released on one of the bottles, a water sample was drawn into the bottle. The sampler was connected electrically to attachments on the Leupold & Stevens Type F water level recorder equipped with a self-starting clock. Power was supplied by two 6 volt dry cell batteries wired in series to make a 12 volt system. The operational sequence of the sampler was as follows:

1. The float on the water level recorder would rise when water started to flow and an automatic clock starter actuated the recorder clock.

2. As the clock ran, it caused the recording pen to move across the sheet. An attachment to the recording pen periodically completed an electrical circuit as the pen traveled across the recorder.

3. Upon completion of the electrical circuit, a solenoid was actuated which tripped a mechanism which released the vacuum held in one of the bottles.

4. As the vacuum decreased, the water sample was collected through individual hoses connecting each bottle to the sampler head.

Figure 11 shows an overall view of the interior of the sampler. Each bottle had an intake hose with a solenoid operated clamp which pinched off a rubber hose to contain the vacuum in the bottle until released. A vacuum of about 24 in. Hg was applied to the 12 individual bottles, contained within the sampler. The water sample entered the bottle which was under negative pressure. The sampler head consisted of glass tubing connected to Tygon tubing. The glass tubing was protected by an aluminum tubular shield.

Figure 12 shows some of the details of the hose clamping system. The hose clamps were manually latched and an electrical solenoid released the clamp as the solenoid received a signal from the recorder. With all of the solenoid-operated clamps engaged vacuum was applied to the bottles using a vacuum pump and a portable generator, through a common manifold. The manifold was located on the backside of the crosspiece at the top of the sampler through which the 12 hoses pass. After the proper amount of vacuum had been attained, a Hoffman "H" clamp was tightened on each hose to seal each bottle individually until the vacuum was released by the solenoid clamp. For the top row of the solenoid-operated clamps shown in Figure 5, the two hoses on the left are pictured in the clamped position whereas the four clamps on the right have been opened by the solenoid.

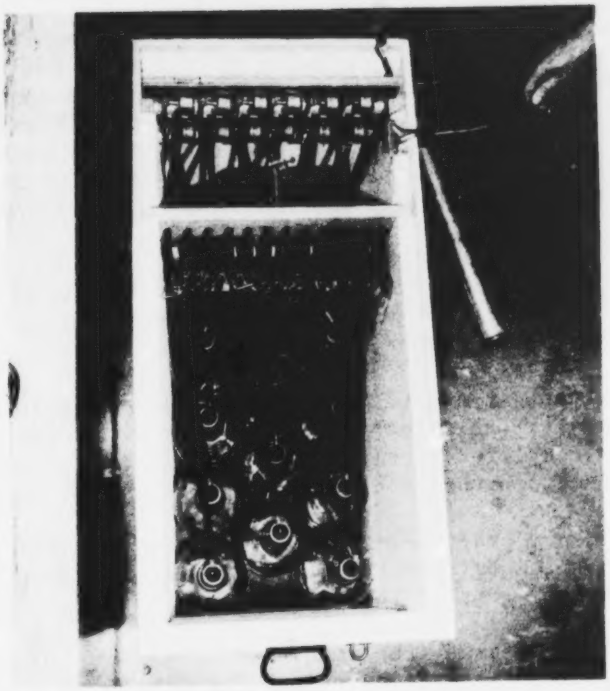


FIGURE 11. - Interior view of sampler.

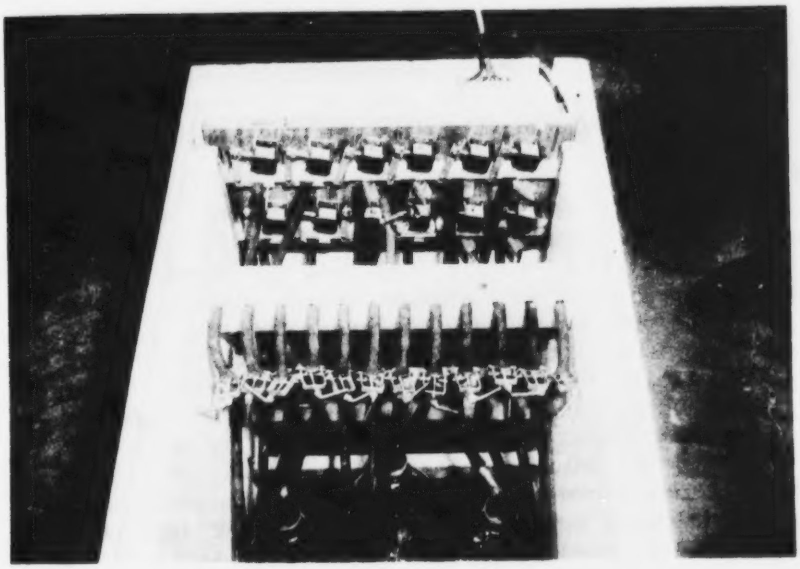


FIGURE 12. - View of solenoid controlled clamping system for the sampler.

Figures 13 and 14 shows the modifications made to the Leupold and Stevens Type F water level recorder. A multi-conductor cable connected the sampler, where the battery and solenoids were contained, to the recorder by the multi-connector plug shown in Figure 13. A plastic strip with two rows of screws was mounted directly above the pen path on the recorder. These screws served as electrical connections which were wired to the battery and solenoid clamps in the sampler through the multiconductor dable. An attachment fastened on the pen carriage served as a switch to make contact with both screws as the pen traveled the length of the chart drum.

The spacing of the contacts along the plastic strip determined the time intervals at which samples were collected. The particular level recorder shown in Figure 14 was equipped for a four hour runoff event, and after starting would collect 12 individual samples in succession. Time intervals for collection were two samples each at 5 minute intervals, 2 at 10 minute intervals, 4 at 20 minute intervals, and 4 at 30 minute intervals.

After each runoff event the samples and the stage level chart were removed from the sampler and the sampler was reset. A single liquid composite sample was made using individual aliquots representing the flow volume at the time of collection of the individual samples. This single composite was used for bacteriological, liquid pesticide, chemical, and physical tests. A separate mud sample for pesticide determinations was usually collected. This mud sample was obtained after the runoff was finished by scraping mud deposits from various points where fresh sediment was apparent. The mud sample was used as an indication of the pesticide associated with sediment. If fresh sediment accumulations did not seem obvious, mud samples were not taken.

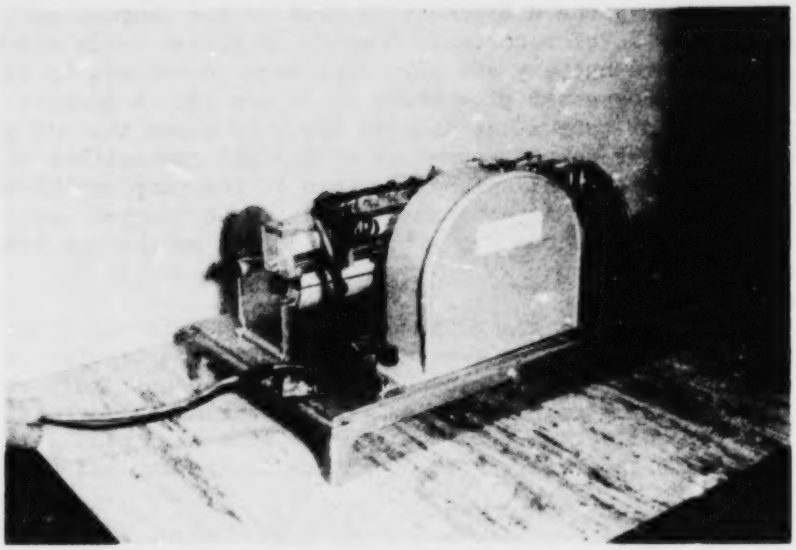


FIGURE 13. - Type F water level recorder with modifications to activate automatic sampler.

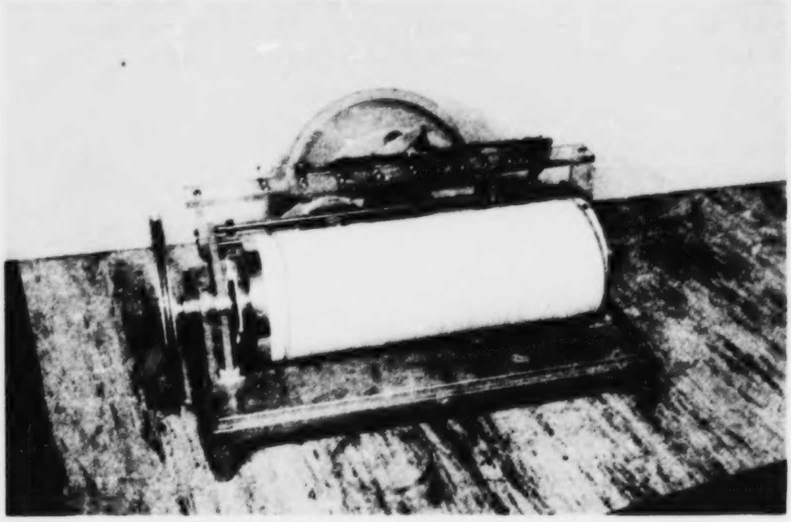


FIGURE 14. - View of level recorder showing mounting of plastic strip.

SECTION VII

LABORATORY METHODS

PHASE I

Phase I is the designation given to those activities which were carried out during the initial year of the project. These activities included searching for the selection of the field research sites, purchasing and installing field and laboratory equipment, and collecting and storing runoff samples until the purchased laboratory equipment was available for some of the analytical determinations.

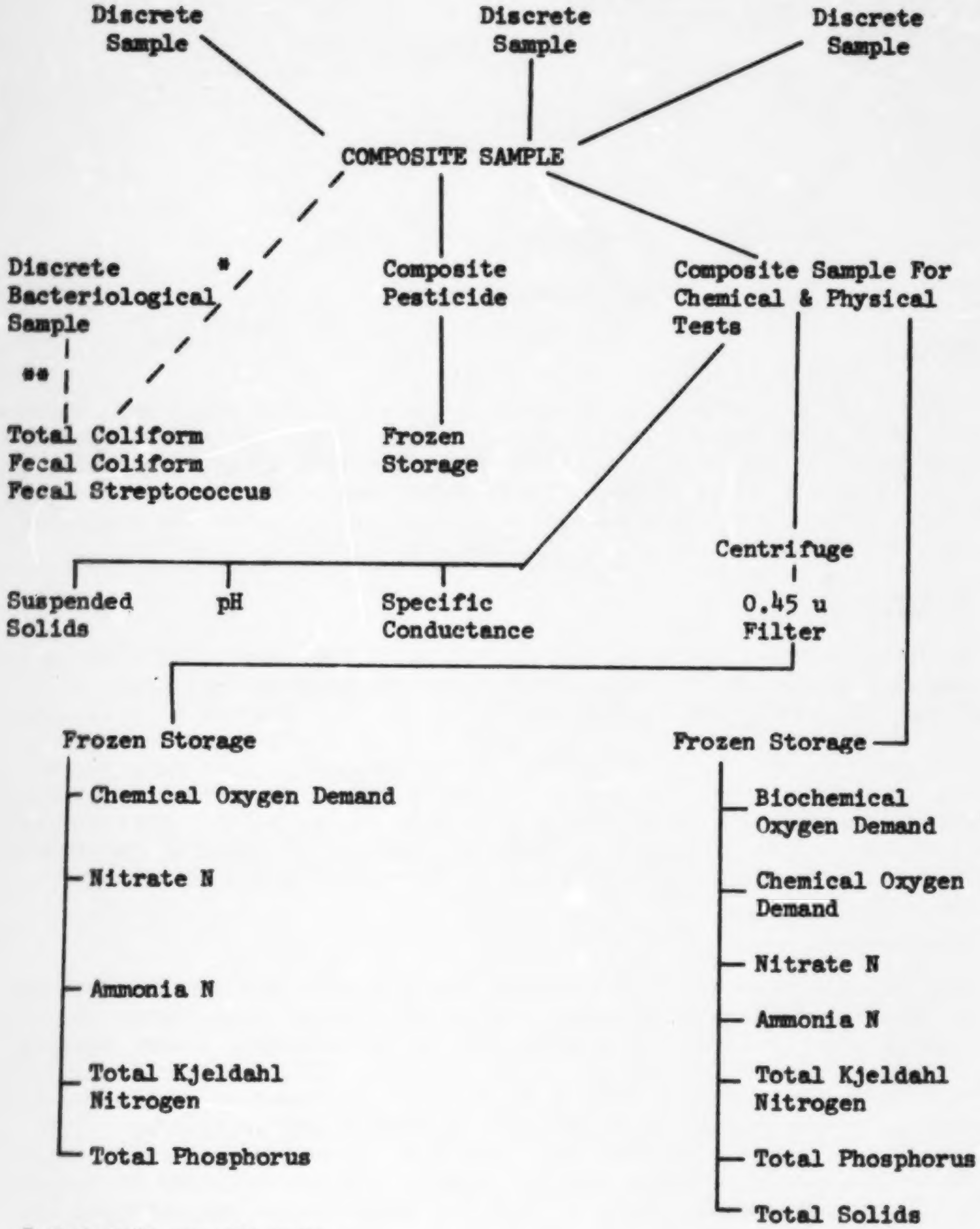
Background

Funding for the project was authorized as of February 1, 1970 and a search for acceptable research sites was immediately initiated, although the search was hampered by the snow cover present at this time. Four suitable sites were soon located and the field measuring equipment was ordered in an attempt to secure acceptable flow data for the spring snowmelt events. Unfortunately, a preseason rainfall on frozen ground preceded the installation of the field equipment. Consequently, total quantities of runoff pollutants could not be computed for the four research sites which were instrumented during the initial year.

Procedures

The flow diagram which was followed for the treatment and analysis of all the runoff samples obtained during 1970 is shown in Figure 15. Sterile plastic bags were used to collect the snowmelt runoff samples for bacteriological tests and total coliform (TC), fecal coliform (FC) and fecal streptococcus (FS) analyses were performed on each discrete sample. For purposes of comparison, composite MPN values for TC, FC and FS were calculated from the individual snowmelt samples and the flow information. During rainfall events, the bacteriological determinations were conducted on a composite sample which was obtained by proportioning the individual samples collected by the automatic sampler.

Determinations for total coliform, fecal coliform, fecal streptococcus suspended solids, pH, and specific conductance were made on fresh samples. All remaining determinations were conducted on frozen samples


Discrete Sample
Discrete Sample
Discrete Sample
COMPOSITE SAMPLE
Discrete Bacteriological Sample
*
**
Composite Pesticide
Composite Sample For Chemical & Physical Tests
Total Coliform
Fecal Coliform
Fecal Streptococcus
Frozen Storage
Centrifuge
Suspended Solids
pH
Specific Conductance
0.45 u Filter
Frozen Storage
Chemical Oxygen Demand
Nitrate N
Ammonia N
Total Kjeldahl Nitrogen
Total Phosphorus
Frozen Storage
Biochemical Oxygen Demand
Chemical Oxygen Demand
Nitrate N
Ammonia N
Total Kjeldahl Nitrogen
Total Phosphorus
Total Solids

* Rainfall runoff only
** Snowmelt runoff only

Figure 15. - Flow diagram for treatment and analysis of samples during Phase I.

which had been stored for about six months. It was subsequently shown that several of these determinations are affected by frozen storage and therefore some of the results from Phase I are not directly comparable to those obtained during Phase II. The primary reason for using the frozen storage technique was the unavailability of the necessary analytical equipment until the fall of 1970.

Pesticide values reported during Phase I are not valid because of the storage method used. Composite pesticide samples were frozen in heavy duty plastic bags prior to analysis. Known standard samples were stored in the same manner and revealed that a majority of the pesticide in the sample could not be recovered after storage.

PHASE II

Phase II is the designation given to those activities which were carried out during the final two years of the project. Phase II activities were basically the routine field maintenance required, collection of samples, and data acquisition and interpretation. Field and laboratory equipment had been purchased, installed and tested for reliability. Prolonged storage of the samples was not a problem during this phase.

Sample Storage and Handling

The methods of sampling runoff were the manual collection of individual samples during snowmelt runoff, and the automatic and manual collection of samples during rainfall runoff. A single composite sample for each event was then made from the individual samples. Each individual sample represented a certain percentage of the total flow, therefore the volume taken from the individual sample was this percentage multiplied by the required volume of the composite sample.

Figure 16 depicts the processes followed during snowmelt runoff. Discrete samples were held at 4°C prior to compositing. Compositing was completed within 12 to 28 hours after sample collection. Part of the composite sample was then frozen for later analysis. Laboratory determinations on the remaining sample portion were finished within one week of initial collection. Samples were stored at 4°C during this period. Passing the sample through the 0.45 micron filter allowed the determination of the soluble fraction of certain constituents; namely, chemical oxygen demand, total kjeldahl nitrogen, and total phosphorus.

Certain determinations were thought to be affected by freezing and these were conducted on fresh, unfrozen aliquots. All determinations, which were carried out on a sample which was preserved by freezing, were verified by utilizing a test set of samples to determine the concentration of the particular parameter before and after frozen storage. Because of time limitations during snowmelt runoff, the ammonia determination was not performed as this constituent would be included in the total kjeldahl nitrogen results.

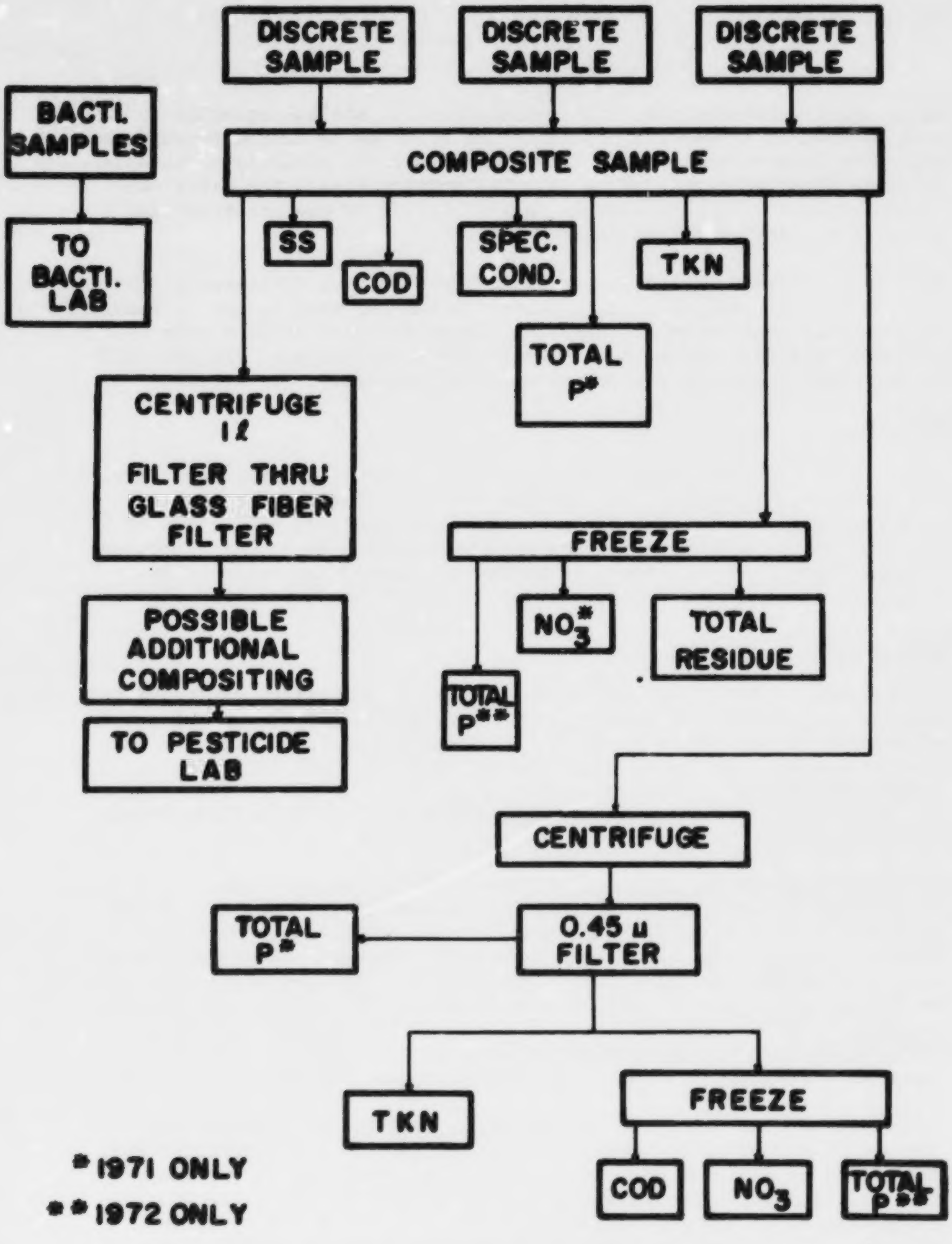

DISCRETE SAMPLE
DISCRETE SAMPLE
DISCRETE SAMPLE
BACTI. SAMPLES
COMPOSITE SAMPLE
TO BACTI. LAB
SS
COD
SPEC. COND.
TKN
TOTAL P*
CENTRIFUGE 1 ℓ
FILTER THRU GLASS FIBER FILTER
FREEZE
NO3*
TOTAL RESIDUE
TOTAL P**
POSSIBLE ADDITIONAL COMPOSITING
TO PESTICIDE LAB
CENTRIFUGE
TOTAL P*
0.45 µ FILTER
TKN
FREEZE
COD
NO3
TOTAL P**
* 1971 ONLY
** 1972 ONLY

FIGURE 16. - Flow Diagram for snowmelt determinations during Phase II.

Nitrate-nitrogen, soluble chemical oxygen demand, and total residue were determined on snowmelt samples which had been preserved by freezing. In addition to these three determinations, the effects of freezing on total phosphorus and total kjeldahl nitrogen were also investigated. A t-test based on a procedure presented by Steel and Torrie (60) was used to determine the significance of the freezing effects, and the results are shown in Table 3. The results are based on the average of duplicate determinations for 10 samples. It can be seen from the table that only total kjeldahl nitrogen was significantly affected by frozen storage of snowmelt samples. All values for total kjeldahl nitrogen reported herein for Phase II were obtained by determinations performed on fresh, unfrozen samples.

TABLE 3. - Summary of Analysis of Variance of Freezing Effects on Analytical Determinations of Snowmelt Samples

Determination	t	t @ 0.05 Level	Remarks
Total phosphorus	0.083	2.262	Not significant
Total Kjeldahl nitrogen	2.41	2.306	Significant
Nitrate	0.316	2.262	Not significant
Soluble COD	1.92	2.262	Not significant
Total residue	0.91	2.365	Not significant

Initially during 1971 the pesticide determinations were made on each snowmelt composite sample. Because the concentrations were below the analytical limits of the tests, later pesticides analyses were made on a sample representing a composite of two or three days flow.

The analytical determinations of the rainfall runoff samples were made on fresh, unfrozen composites. All determinations made of the snowmelt samples were also made of the rain runoff samples. In addition, ammonia was determined, and pesticide analyses were conducted on a sediment sample as well as the water portion of the runoff. Rainfall runoff samples were stored at 4°C until tested. All determinations on rainfall runoff samples were completed within one week of collection.

Bacteriological Determinations

Total coliform, fecal coliform, and fecal streptococcus determinations for all composite samples were made under the direction of Dr. Paul Middaugh. The density (MPN/100 ml) was found using the multiple-tube fermentation technique described in the 12th and 13th Editions of "Standard Methods" (61) (62). Both the total coliform and fecal streptococcus technics utilized the confirmed test; the total coliforms were confirmed by using brilliant green lactose bile broth, and the fecal streptococci were confirmed by using ethyl violet azide broth. Fecal coliforms were determined using technics requiring ED medium and a temperature of 45°C.

During periods of snowmelt runoff, bacteriological samples were collected in sterile plastic bags, stored at 4°C, and then composited according to flow. Tests were started on the composite samples approximately 16-24 hours after initial collection.

Individual bacteriological samples were not collected for rainfall runoff events. A single composite sample was made from the discrete samples which the automatic sampler had collected, and the bacteriological sample was a portion of this composite sample. Tests were initiated on the bacteriological samples within approximately 12 hours after initial collection by the automatic sampler.

Pesticide Determinations

Pesticide analyses were performed under the direction of Dr. Y. A. Greichus. All water samples were analyzed by the procedures described in The Identification and Measurement of Chlorinated Hydrocarbon Pesticides in Surface Waters (63). The following insecticides were included: lindane, heptachlor, aldrin, heptachlor epoxide, DDE, DDD, DDT, and dieldrin; while herbicides included the triazines, simazine and atrazine.

On all snowmelt samples, pesticide data were obtained on only the runoff waters; sediment was excluded by filtration according to "Standard Methods" (62). On rainfall runoff samples, data were obtained on both the water and sediment portions of runoff.

Pesticide composites for rainfall runoff represented a single event. However, because of the low concentrations of pesticides in the snowmelt runoff; the snowmelt samples were composited over a longer time period which was normally of two to three days duration.

Determinations Using the Auto Analyzer

Several of the analyses were made by using a basic autoanalyzer system as manufactured by the Technicon Corporation. Components used included proportioning pumps and manifolds, heating baths, a continuous digester, colorimeter, and recorder. Tests conducted using the auto-analyzer were soluble chemical oxygen demand, raw and soluble total phosphorus, raw and soluble total kjeldahl nitrogen, ammonia, and nitrate.

Methods used on the autoanalyzer are based on "Standard Methods" (61). They are basically the same procedures as used in the laboratories of the Environmental Protection Agency and listed in Methods for Chemical Analysis of Water and Wastes 1971 (64). Specific laboratory methods used were obtained from the Technicon Corporation and are shown in Table 4.

Industrial Method 1-68W was used for total phosphorus although the method is specified for orthophosphate. Total phosphorus samples were prepared by sample digestion on a hot plate as described in Methods for Chemical Analysis of Water and Wastes 1971 (64). Glassware was cleaned with 1:1 HCl.

TABLE 4. - Autoanalyzer Methodology

Test	Technicon Methodology	
Soluble chemical oxygen demand	Industrial Method	26-69W
Raw and soluble total phosphorus	Industrial Method	1-68W
Raw and soluble total kjeldahl nitrogen	Industrial Method	30-69A
Ammonia	Industrial Method	19-69W
Nitrate	Industrial Method	32-69W

Other Physical and Chemical Determinations

All remaining analytical determinations were conducted in accordance with "Standard Methods" (61) (62). Parameters so measured were total suspended matter, total residue, chemical oxygen demand, and specific conductance.

Total suspended matter was determined by passing the sample through glass fiber filter disks positioned on a membrane filtering apparatus. The filters were dried at 103°C and allowed to cool in a desiccator before weighing. Blanks were handled in the same way as the filters to account for any weight loss of the filters upon drying. Suspended matter was computed from the weight gain obtained after drying.

The test for total residue on evaporation specifies a drying temperature of 103°C to minimize losses of volatile materials which may be present. Coors porcelain evaporating dishes were used, and were predried to a constant weight. Sample volumes of 100 ml were evaporated on a water bath and the dishes were dried to a constant weight in an oven, cooled and weighed. The weight gain represented the total residue of the sample.

Chemical oxygen demand determinations were conducted using the standard dichromate reflux method with sample volumes of 20 ml. Specific conductance values were obtained using a Type RC conductivity bridge as manufactured by Industrial Instruments, Inc. of Cedar Grove, N. J. The cell constant was checked periodically and the samples were allowed to warm up to room temperature before the conductivity was measured. Conductivity valves were adjusted to a value at 25°C by using a graph based on a 0.01 M KCl solution.

SECTION VIII

DATA AND RESULTS

CLIMATOLOGICAL SUMMARY

All the research sites are located within Brookings County and within 20 miles of Brookings, South Dakota; an area that annually receives about 20.4 inches of precipitation. Over 80% of the precipitation occurs as rainfall, and the annual snowfall averages 23 inches. Brookings is located in east central South Dakota and enjoys a continental climate. The only nearby water is the Big Sioux River about six miles west of Brookings. Some small lakes are 15 to 30 miles west and northwest (65).

Temperatures annually rise above 100 degrees in summer and drop to 20 degrees below zero or lower in the winter. The last frost will usually occur before May 18, and the average date for the first frost in the fall is September 22 (65).

Prevailing winds average about 10 mph from the south during the summer months and usually average about the same speed from the northwest during the winter months. Wind velocities of over 50 mph are common and may occur at anytime, but are most common during a summer thunderstorm (65).

Evaporation normally exceeds the precipitation with an annual average of 47 inches from a Weather Bureau Class A evaporation pan. The nearby shallow lakes average about 33 to 34 inches of evaporation per year (65).

Table 5, a precipitation summary, indicated that 1971 was probably about an average year with regard to precipitation, while 1972 was considerably above average. The rainfall data collected at Sites No. 2 and 8 are considered to be more accurate because recording rain gages approved by the United States Weather Bureau were used at these sites. The other sites were equipped with plastic Tru-Chek gages as manufactured by the Edwards Manufacturing Co. of Albert Lea, Minnesota. Because Sites No. 1 and 2 are adjacent, and Sites No. 8 and 9 are adjacent; it appears that the recorded rainfall from the plastic rain gages averaged about 3% to 5% high.

TABLE 5. - Precipitation Summary at Research Sites From Mid-March to Mid-November*

Site No.	Type of Gage	1971 Rainfall (in.)	1972 Rainfall (in.)
1	Plastic	19.96	26.56
2	Recording	19.05	24.49
3 & 4	Plastic	19.70	25.88
7	Plastic	19.64	26.35
8	Recording	18.11	27.93
9	Plastic	18.58	28.93

* Average annual precipitation for Brookings, S. D. from mid-March to mid-November is about 18.4".

Table 6 shows the increase in the number of runoff events for the 1972 season. Comparing the total runoff events for the three years causes speculation regarding the amount of runoff which results from rainfall during a normal year.

TABLE 6. - Frequency of Runoff from Rainfall

Year	Average No. of Days of Rainfall	Actual Days of Rainfall Runoff	Number of Events of Rainfall Runoff
1970	46	2	4 *
1971	49	2	2
1972	64	14	30

* Four of seven sites were operable during 1970

Actually 1971 can not be considered as a normal year with respect to rainfall. While the total amount of rainfall was normal, the seasonal distribution of the rainfall was quite abnormal. Almost one-third of the total rainfall came after August which resulted in limited runoff because of the established crop cover.

Considerably more rainfall than usual was recorded during 1972. A substantial amount of this rain was received in late spring and early summer before cover became established on the cultivated fields which was reflected in the large increase of rainfall runoff events for 1972. In May of 1972, a total of 9.35 in. of rain was recorded at Site No. 8 and 7.97 in. was recorded at Site No. 2. This May of 1972 was the wettest May on record and ranks as the second or third wettest month since record keeping began in 1893 (65).

Therefore, as far as rainfall runoff is concerned; two of the three years of study can be considered as approaching the maximum and minimum conditions. The second year, 1971, was a minimal rainfall runoff year because the precipitation occurred when the ground cover was well established. The third year, 1972, approached a maximum rainfall runoff condition because much of the rainfall occurred when the ground was unprotected. Both of these years occurred during Phase II and complete runoff data were obtained.

Several factors affect both the quantity and quality of surface runoff. Some of these factors are surface and subsoil type and formation, ground cover, intensity and frequency of precipitation, the total amount and duration of rainfall, the topography of the area, land management practices, and the time of the year.

To fully evaluate the effect of each factor was beyond the scope of this project. However, some of the above factors are quite pertinent to the runoff patterns obtained for a particular site; and they will be referred to as the runoff results are presented.

RUNOFF ANALOGIES

Figure 17 illustrates the runoff patterns for each of the two project years in Phase II. A comparison between the two years regarding the relative proportion of snowmelt and rainfall runoff is quite interesting.

The first year had an almost negligible amount of rainfall runoff. Figure 17 shows that all of the sites, with the exception of Site No. 8, had snowmelt as their only surface runoff. Rainfall runoff accounted for only about 0.2% of the year's runoff volume on this single site.

Figure 17 also indicates that the rainfall runoff for all the sites during the second year was substantially greater than for the first

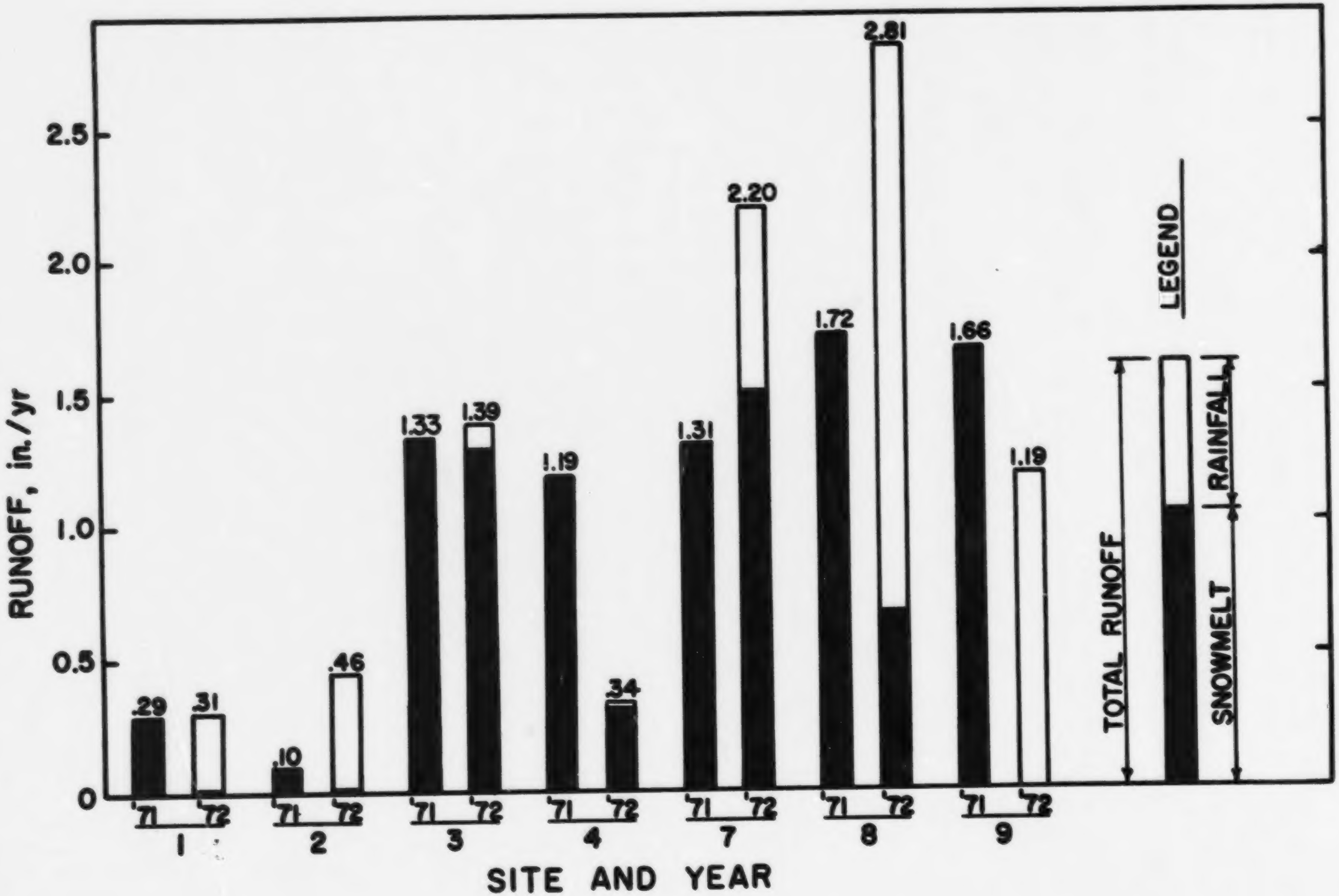


FIGURE 17. – ANNUAL RUNOFF PATTERNS FOR PHASE II.

year. The primary reason for this difference was the change in seasonal rainfall distribution. These figures also point out variations in the amount of snowmelt runoff. Only Sites No. 3 and 7 experienced the same approximate magnitude of snowmelt runoff, and Site No. 9 did not have snowmelt runoff. The previous year Site No. 9 had 1.66 in. of snowmelt runoff.

Obviously the conditions affecting snowmelt runoff will not be the same from year to year. Snowfall will vary, evaporation will change, the rate of thawing for the soil and the snow will differ; and in general, it is difficult to correlate conditions from year to year. However, it was very apparent to even the most casual observer that only small amounts of snowmelt runoff would be measured on Sites No. 1, 2, 8, and 9 during 1972. All four of these sites had been in the fallow state since the fall of the previous year and the wind had kept the sites almost clear of snow throughout the winter. The effects of wind erosion were evident.

A small amount of snow was retained on Sites 1, 2, and 9. The snow which melted on Site No. 9 never reached the measuring flume because of the small natural depression present. Some snow was retained near the summit of the drainage basin on Site No. 8 as this particular segment of the area was not plowed.

Sites No. 3 and 7 show the effects of a permanent grass cover as they both retained the snow and had a volume of snowmelt runoff which was very similar. Although Site No. 4 has snowmelt runoff considerably in excess of the cultivated fields in its vicinity, and because it too has a permanent grass cover; it would be expected to have a snowmelt volume resembling that of Sites No. 3 and 7. This was true during 1971 but not during 1972. A reason for the lesser volume of snowmelt runoff for Site No. 4 for 1972 was not apparent.

Depending upon weather conditions, snowmelt runoff may occur in one or two day spurts or for a sustained period of several days. During the second year three separate snowmelt runoff periods of two, three, and four day's duration occurred. Snowmelt runoff came in one period during ten consecutive days for the third year. The snow was usually gone by the middle of March and may have begun to thaw in late January or February. After the ground thawed, additional snowfall did not produce surface runoff, but was absorbed into the soil.

Figure 13 shows the distribution of rainstorm events based upon the magnitude of the event. The minimum amount of rain which caused runoff to occur was 0.40 in. The average amount of rain causing runoff was 1.31 in. From the figure, this average of 1.31 in. implies that surface runoff from rainfall can only be expected about five times a year. The total amount of rainfall in a rainfall event is only one factor, but certainly rainfall runoff from agricultural lands is not a

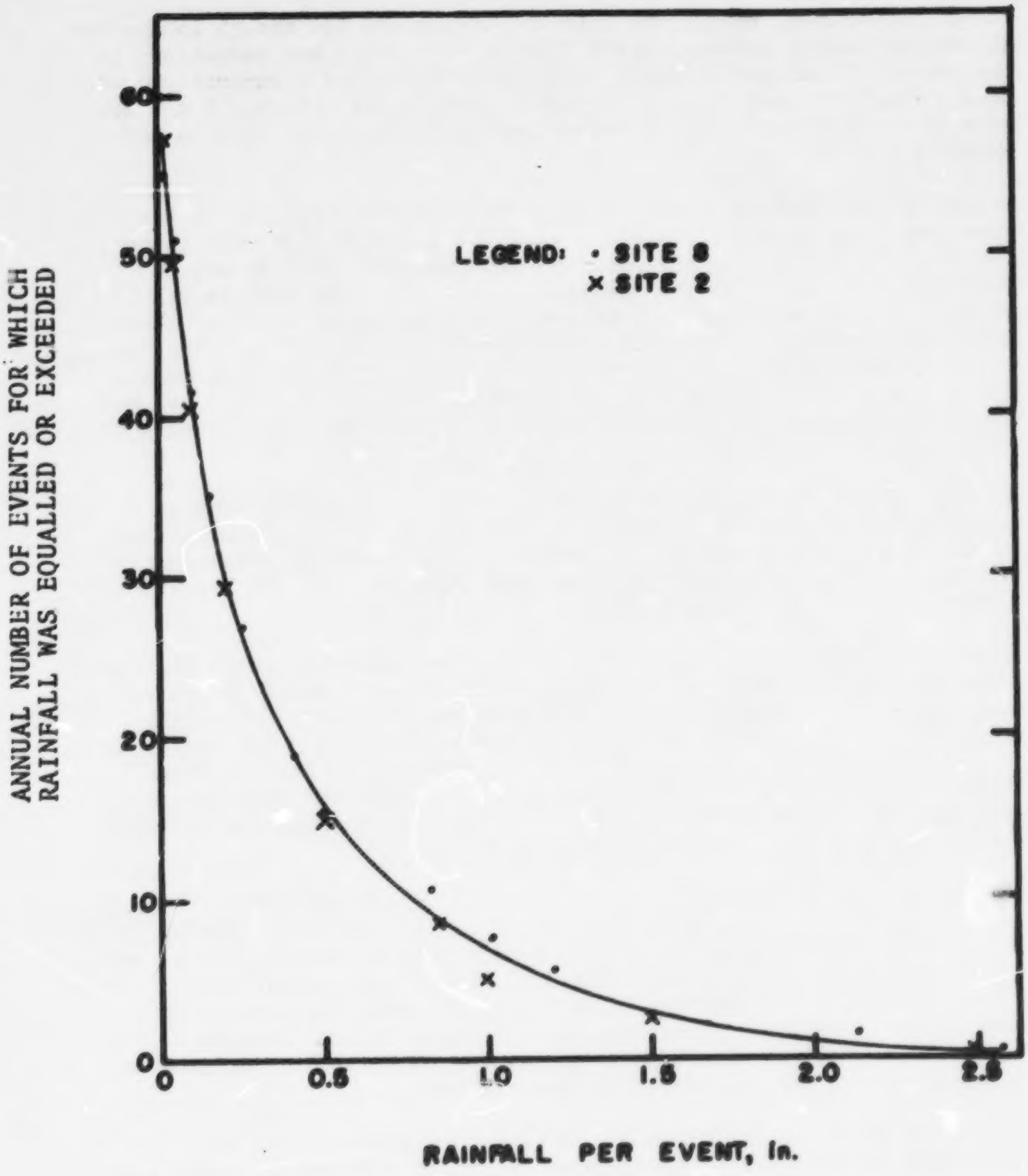


FIGURE 18.—Distribution of rainfall events.

frequent occurrence for the geographic area studied. It is important to remember how infrequently runoff occurs if possible control measures are being considered.

Figure 19 illustrates the different hydrographs obtained when the storm intensity was the main variable. Both runoff events took place on the same site in the same year so the topography is identical and the crop cover was similar. Both storms applied about the same amount of rain to the drainage area, about 1 in. of rainfall. The event of May 29, 1972 had 0.87 in. of rain, and the event of July26, 1972 had 1.20 in. of rain. The runoff resulting from both events was nearly identical, being within about 4% of each other.

The hydrographs reflect a change in the ground condition and a difference in rainfall intensity. The rainfall of May 29 was a low intensity storm on a relatively saturated soil which resulted in a long duration runoff event. The maximum intensity for a 10 minute period was 0.6 in.hr. This same intensity and rainfall may not have caused runoff if the ground had been drier. The rainfall event of July 26 had a much higher intensity and the ground was considerably drier. The maximum 10 minute intensity for this storm was 2.7 in./hr. The average rainfall intensity for the entire rainfall period was 0.16 in./hr for the May 29 event and 1.1 in./hr for the July 26 event.

Differences between the two events with respect to the amount of material which was washed off the field is presented. The high intensity storm of July 26 contributed almost 25 times the suspended solids load of the May 29 event. The impact of the raindrop as it strikes an unprotected soil is undoubtedly one of the important contributing factors to soil erosion (8). Pollution may result when the dislodged soil and other materials are washed off the field in runoff.

The amount of runoff, the total rainfall, and the periods of maximum rainfall intensity were extremely variable for those storms which caused runoff, as well as for some similar storms which did not cause runoff. It is virtually impossible to predict if a rainfall event will cause runoff when considering only amount and intensity of rainfall. Other factors such as ground cover, antecedent rain, and condition of the soil must also be considered.

PHASE I

A complete summary of all the data collected during Phase I can be found in the appendices. The primary knowledge obtained during this phase centered around biochemical oxygen demand (BOD), pH, and information regarding pollutional constituents in snowmelt runoff.

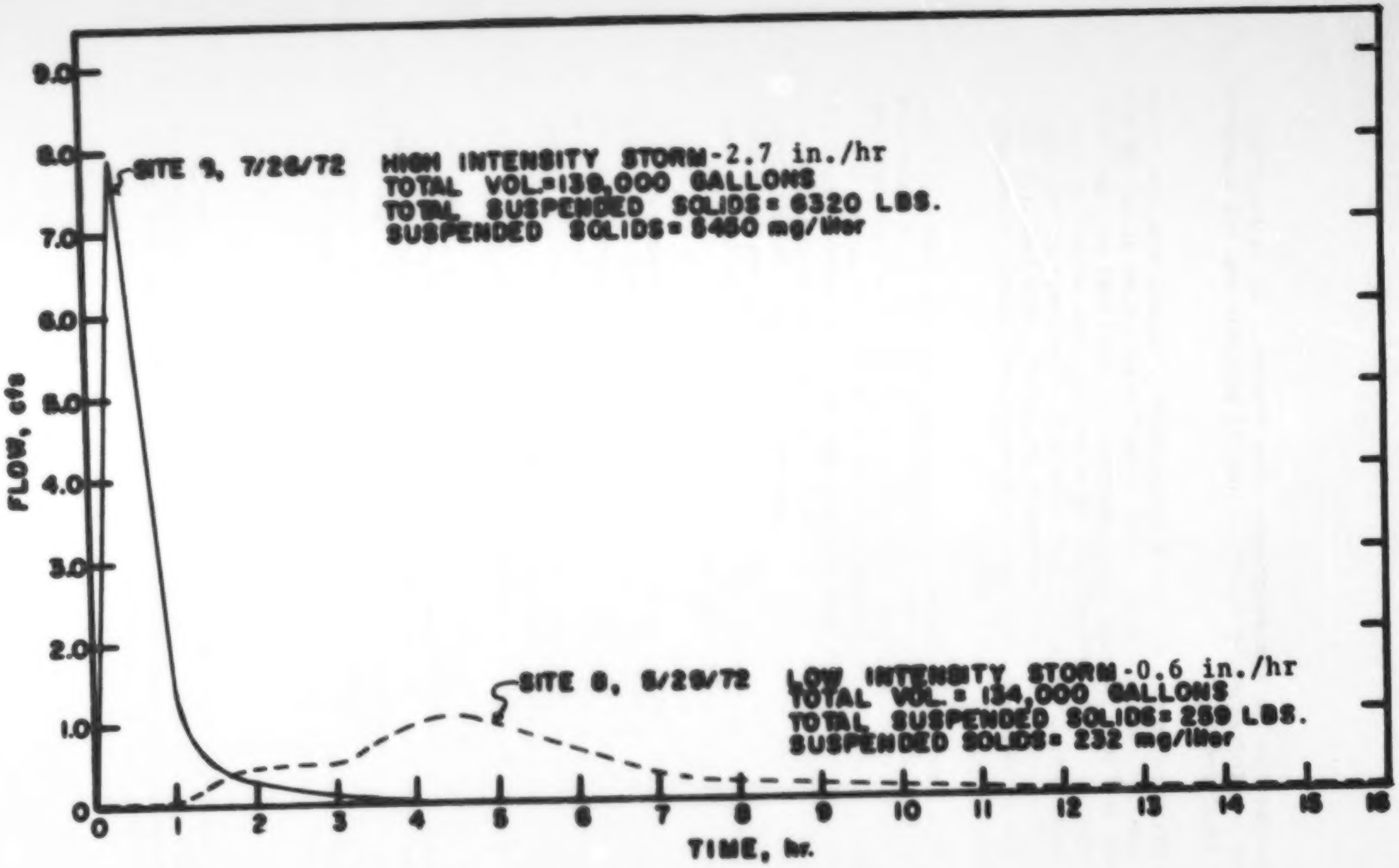


FIGURE 19.—Hydrograph comparison of a low intensity storm and a high intensity storm.

Biochemical Oxygen Demand

Both 5-day and ultimate BOD values were obtained for the runoff samples collected during Phase I. BOD determinations were carried out on frozen samples which had been stored for several months. All samples were essentially run in duplicate using 100% and 50% sample portions and a Weston - Stack DO probe. The DO was monitored in a 300 ml BOD bottle with the samples being reaerated in the bottle as required. Settled primary effluent was used to seed the dilution water. Therefore, the two BOD values obtained for each runoff sample, one value from a 100% sample bottle and one value from a 50% sample dilution, should give an indication of the effects of seeding on a previously frozen runoff sample.

Fogarty and Reeder (66) evaluated the BOD results from frozen and fresh samples, as well as seeded and unseeded samples. Storage periods for various periods up to six months were utilized. They concluded that there wasn't any difference between BOD values obtained by using fresh and frozen samples, as long as the frozen samples were seeded prior to analysis. A difference in the BOD values for the seeded and unseeded samples could not be detected for the runoff study being reported herein, and the two values were simply averaged before data interpretation.

Table 7 shows the important BOD relationships which were obtained from some selected samples. Complete data for all the runoff samples from Phase I can be found in Appendix A.

A normal domestic waste is usually considered to have satisfied its carbonaceous oxygen demand during the first 20 days. The oxygen demand which is exerted during these first 20 days is called the first-stage or ultimate demand. A normal domestic waste will frequently have a deoxygenation factor of from 0.1 to 0.2 Referring to Table 7, it can be seen that the deoxygenation factor was much lower than this. Therefore, the ultimate BOD was calculated from the oxygen consumed by the organisms until the oxygen exertion rate became very small. This time period was usually about 50 days and ranged from 42 to 62 days. The ultimate first-stage BOD values were corrected slightly for nitrification by using blanks for the same period of time. This correction for nitrogenous demand was small because of the low ammonia concentrations present in the runoff samples.

The 5-day BOD values were always quite low with most values at 15 mg/l or less. The maximum 5-day value obtained was 21 mg/l from Site No. 4 on March 23. The low BOD to COD ratios indicate that much of the organic matter is not readily available for biological oxidation. This is probably representative of the cellulose and hemi-celluloses which would degrade very slowly. The slow degradation is also substantiated by the low deoxygenation factor.

TABLE 7 - Biochemical Oxygen Demand and
Related Factors for Agricultural Runoff

Sample, Site & Date 1970	5-day BOD mg/1	Ultimate BOD, mg/1	5-day BOD as a Percentage of the Ultimate BOD, %	Deoxygenation Factor	COD, mg/1	BOD/COD
4, 3/23	21	75	28.0	0.03	131	0.16
2, 4/1	11	32	34.4	0.04	62	0.18
1, 4/5	17	48	35.4	0.04	91	0.19
3, 3/23	18	70	25.7	0.03	105	0.17
2, 3/23	16	44	36.4	0.04	82	0.19
1, 3/23	13	53	24.5	0.03	105	0.12
1, 5/31	10	47	21.3	0.02	1780	0.006
2, 5/31	9	42	21.4	0.02	980	0.01

pH

A laboratory pH meter was used to determine pH on the runoff samples which were collected during Phase I. Only minor variations in pH were detected, all the values ranging from 6.8 to 7.8, and this test was discontinued after the initial project year.

One interesting aspect of the pH measurements which were taken was the two narrow ranges of pH which were established for snowmelt and rainfall runoff samples. All snowmelt runoff samples had a pH measurement of between 7.4 and 7.8. All rainfall runoff samples had a pH which measured either 6.8 or 6.9.

Because both of the above pH ranges are near neutral and are acceptable to most water quality standards, additional research to determine the exact cause of the pH drop was not conducted. Very few solids were present in the snowmelt runoff and the slight alkalinity present is thought to be a result of bicarbonates dissolved in the runoff. Precipitation which occurred after the ground was thawed promoted percolation which would allow leaching of the cations. Accumulated organic matter would gradually decompose and generate organic and other acids. Hydrogen ions, supplied by these acids, would replace the leached cations on the topsoil's cation exchange complex. The pH of the rainfall runoff sample is probably lower than its snowmelt counterpart because more soil is lost from a rainfall runoff event than from a snowmelt runoff event.

Snowmelt Runoff

The major portion of the overland runoff from drainage basins in the geographic area studied originated with the melting of accumulated snow. The quality of the samples collected on the individual days was usually quite comparable from day to day even though the quantity of runoff on a particular day may be several times that of the previous day. Consequently, a tentative method of describing the relative quality of the snowmelt runoff was desired.

Because the snowmelt runoff occurs in a cyclic manner with flow increasing during the warm daylight period and diminishing frequently to zero flow during the night when below freezing temperatures occur, the individual samples are representative of discrete runoff events. Consequently, a series of samples collected from a drainage basin can be considered as a statistical distribution of samples and the various characteristics of the samples can be similarly grouped. The median values of the distribution of the various characteristics such as suspended solids, phosphorus, nitrates etc. were selected as being most representative of the overall quality of the snowmelt.

Table 8 contains the median and range of concentration for the chemical characteristics of the snowmelt runoff during Phase I. The number of samples collected and the flow range are also included.

TABLE 8 - Concentrations of Characteristics of Snowmelt Runoff for Phase I

		Site No.			
Characteristic		1	2	3	4
No. of Samples		6	5	3	3
Flow, Hundreds of Gallons	Median	71	64	56	2
	Range	5-136	1-72	11-228	1-9
Total Residue, mg/l	Median	302	187	225	230
	Range	179-890	128-175	222-227	223-258
Suspended Solids mg/l	Median	140	38	34	21
	Range	38-584	6-71	33-75	19-24
Specific Conductance, μMHOS/cm @25C	Median	125	130	202	202
	Range	96-172	110-160	153-208	178-225
Raw Total Phosphorus, mg/l	Median	0.41	0.47	0.60	0.94
	Range	.27-1.13	.36-.66	.48-.72	.68-1.35
Soluble Total Phosphorus, mg/l	Median	0.24	0.34	0.17	0.62
	Range	.12-.68	.17-.39	.08-.30	.37-.77
Raw Total Kjeldahl Nitrogen, mg/l	Median	2.7	3.3	5.1	5.6
	Range	2.5-4.1	2.4-3.7	4.0-6.1	4.5-5.6
Soluble Total Kjeldahl Nitrogen, mg/l	Median	2.1	2.4	3.1	2.1
	Range	1.9-3.0	0.7-2.7	3.1-3.5	1.2-2.4
Nitrate, mg/l N	Median	1.4	0.8	0.2	0.3
	Range	0.8-1.9	0.3-1.4	0.2-1.2	0.1-0.9
pH	Median	7.4	7.4	7.6	7.7
	Range	7.4-7.5	7.4-7.5	7.6-7.7	7.6-7.8
5-day BOD, mg/l	Median	11	15	16	18
	Range	9-17	11-16	14-18	18-21
Ultimate BOD, mg/l	Median	32	42	59	69
	Range	27-53	32-44	52-70	69-75

TABLE 8 - (continued)

Characteristic		Site No. 1	2	3	4
Raw COD, mg/l	Median	82	79	103	131
	Range	56-125	62-82	97-129	105-131
Soluble COD, mg/l	Median	70	83	121	130
	Range	48-93	62-86	93-127	87-140

From Table 8, it can be seen that the total residue of the runoff from the various sites has most generally been between 100 and 300 mg/l. The suspended solids concentrations were found to be 75 mg/l or less in the snowmelt runoff from all of the drainage basins regardless of crop cover with the exception of several samples from Site 1. The corn crop cover on Site 1 prior to the spring of 1970 was probably a contributing factor to the higher suspended solids concentrations of the snowmelt runoff from that site for that period.

When the suspended solids concentrations of less than 75 mg/l for snowmelt runoff are compared to the suspended solids concentrations found for rainfall runoff, the solids carrying capacity of the snowmelt appears somewhat inconsequential. Rainfall runoff events from Site 1 in 1970 ranged up to 15,200 mg/l of suspended solids. The cyclic nature of the snowmelt process probably prevents the development of substantial flows with sufficient velocity to transport large quantities of sediment. Also the snowmelt runoff is not subjected to an energy input to dislodge the soil particles similar to that which occurs when raindrops create a splashing effect during a thunderstorm causing rainfall runoff.

The nutrient properties of the snowmelt runoff were examined by determining the concentrations of phosphorus and nitrogen of the runoff samples. The phosphorus concentrations have been determined by two methods in an attempt to evaluate the relationship of the suspended solids to the available phosphorus in the runoff. The total phosphorus values were obtained after digestion with the silt present and the soluble phosphorus values were determined after the samples were filtered to remove the silt.

From Table 8 it can be seen that the median values for total phosphorus ranged from 0.41 to 0.94 mg/l and soluble phosphorus from 0.17 to 0.62 mg/l considering all sites. It appears that snowmelt runoff is consistently low in phosphorus concentration, usually below 1.0 mg/l total phosphorus and 0.5 mg/l soluable phosphorus; however, even these concentrations are substantially in excess of the 0.1 and 0.01 mg/l of organic and inorganic phosphorus levels which have been quoted as critical values to support nuisance algae growths in lakes. The land cover or cropping practice on the individual basins did not seem to have an important influence on the overall phosphorus concentration of the snowmelt runoff.

The median Kjeldahl nitrogen concentrations of the snowmelt runoff from the various sites ranged from 2.7 to 5.6 mg/l for those samples containing suspended solids (raw total Kjeldahl nitrogen in Table 8) and from 2.1 to 3.1 mg/l after the solids were removed by filtration . Median nitrate nitrogen concentrations of 0.2 to 1.4 mg/l were found. These concentrations would not appear to be limiting to algal growths if the runoff reached lakes and other conditions became optimal.

Concentrations of other constituents such as COD and BOD are similarly low substantiating a general observation that runoff from snowmelt is of comparatively high chemical quality compared to runoff resulting from rainfall. Nevertheless, in this area, it would appear that even though sediment transport does not appear to be a major problem, the nutrient concentrations of the snowmelt runoff are sufficient to support unwanted aquatic growths if the water is impounded.

PHASE II

A complete listing of the data collected during Phase II can be found in the appendices. Sampling and laboratory procedures were sufficiently established to allow interpretation and comparison from year to year and season to season. Investigations during this phase yielded information regarding the bacteriological quality of runoff water, the pesticides carried with runoff, and the chemical and physical characteristics of land surface drainage.

Indicator Organisms in Runoff

Indicator organisms have long been used to designate the bacteriological quality of a water or wastewater. Pathogenic bacteria are rarely isolated routinely, and the sanitary quality of the water or wastewater sample is usually based on the test results for certain indicator organisms.

Routine bacteriological examinations are important mainly in what they imply and not in what they actually determine. The general health implication or possibility of disease transmission is very important. The degree of health hazard is implied from the routine bacteriological determinations.

The most common bacteriological test for water and wastewater samples is the total coliform test. Coliforms are generally the preferred indicator of fecal contamination in water. The majority of the organisms which give a positive coliform test can be grouped into three species: Esherichia coli, Aerobacter aerogenes, and Aerobacter cloacae.

Esherichia coli are normally found in the intestinal tract of man and animals, and they represent about 90% of the coliforms discharged in fecal matter. Aerobacter aerogenes occur naturally on plants, grain, and soil; but they may also be found in the feces of man and animals. Aerobacter cloacae are also found in the feces of man and animals as well as in the soil. The primary disadvantage of the coliform group as an indicator of fecal contamination is that their presence does not always indicate fecal contamination but may be the result of other foreign matter such as grain, plants or soil. This disadvantage is particularly important when evaluating bacteriological determinations from agricultural runoff samples.

Because of the aforementioned disadvantage, other bacteriological indicators of fecal contamination have been proposed. Two of these indicators are those bacteria belonging to the fecal coliform (FC) and fecal streptococcus (FS) groups. Fecal coliforms are the members of the coliform group associated with the feces of man and animals. The predominant member of the fecal coliform group is _E. coli_. Those streptococci which belong to the fecal streptococcus group are, according to the 13th edition of "Standard Methods" (62), as follows:

(1) _Streptococcus faecalis_
(2) _Streptococcus faecalis_ var. _liquefaciens_
(3) _Streptococcus faecalis_ var. _zymogenes_
(4) _Streptococcus durans_
(5) _Streptococcus faecium_
(6) _Streptococcus bovis_, and
(7) _Streptococcus equinus_

A comparison of fecal coliform and fecal streptococcus densities from the feces of warm blooded animals was made by Geldreich (36). He found that the fecal coliform to fecal streptococcus ratio (FC/FS) for all sources other than man was less than one. It has become apparent that the use of both fecal coliform and fecal streptococcus indicators will probably provide more reliable information about the sanitary quality of a water than information based on total coliform data alone. Water or wastewater samples with FC/FS ratios of more than one can be said to be contaminated by human feces and should be regarded as containing possible pathogenic organisms. Samples with FC/FS ratios of less than one are said to be contaminated from a nonhuman source, and the resulting health hazard is less than the hazard resulting from human sources.

All of the research sites are located in fairly remote areas and human fecal contamination was not expected. About 10% of the 123 runoff samples had fecal coliform counts higher than the fecal streptoccus enumerations. The previous statement regarding the FC/FS ratio being less than one for a sample from a nonhuman source would appear to have about a 90% confidence level. Because of uneven bacterial distribution in a sample, the precision of the multiple tube fermentation test is considered to be rather low. A 90% confidence level is actually quite high, and should be considered as satisfactory. Even though the indicator organism counts became quite high at times, it would appear that the actual health hazard was low.

Most water quality standards specify total coliform and/or fecal coliform as parameters to be considered when evaluating surface waters. Some recommended limits of these indicators are shown in Table 9.

TABLE 9 - Recommended Limits of Bacteriological Indicators in Surface Waters

Beneficial Use	Total Coliform	Fecal Coliform	Reference
Public Water Supply (Minimal treatment)	50/100 ml		McKee and Wolf (67)
Public Water Supply (Conventional treatment)	10,000/100 ml	2,000/100 ml	FWPCA (68)
	2,000/100 ml		(67)
Recreation (Limited Contact)		1,000/100 ml	(68)
	1,000/100 ml		(67)
Recreation (Primary Contact)		200/100 ml	(68)
	240/100 ml		(67)
Irrigation	5000/100 ml	1000/100 ml	(67)

A method described in Steel and Torrie (60) was used to assess the bacteriological data. The logarithm of the density of the indicator organism was regressed on the percent of time that the density was equalled or exceeded. The regression lines were computed for the various crop covers representing all the samples obtained from runoff from a particular ground cover. In other words, data for the fall-plowed regression lines include results from Site No. 1, 2, 8, and 9 for 1972; while data for the pasture regression lines are from samples from only Site No. 7, but the samples were collected over a two year period.

Figure 20 displays the effect of different crop covers on the frequency of total coliform counts present in snowmelt runoff. In general, the runoff from fields which had minimum cover showed higher total coliform densities. The plots of the coliform counts from those fields with heavier cover are similar. Fields with heavier cover are those with oats stubble, permanent brome grass and alfalfa, and permanent pasture; and the regression lines from these fields exhibit low coliform densities and have similar slopes. One regression line has a disparate slope, and the plot for this line was based upon data taken from fields which were fall plowed and remained barren through the winter.

When comparing the criteria of Table 9 with the actual data for Figure 20, it can be seen that the total coliform limits for the different beneficial uses are often exceeded. Criteria for only the beneficial use category of domestic water supply needs to be considered because the criteria for the beneficial uses of recreation and irrigation would apply only during their respective seasons. It is doubtful that criteria for recreation and irrigation would apply when snowmelt runoff was occurring.

The average total coliform density to be generally considered is about 5,000/100 ml, from Table 9. The criteria listed in Table 9 apply only to stream water quality. However, it is important to compare these criteria to the quality of agricultural runoff water because the runoff may contribute water to the stream and the runoff will affect the stream water quality. Referring to Figure 20, this value was exceeded about 50% of the time for those fields with heavy ground cover and more than 50% of the time for those fields with minimum cover. For the fields in fallow, the 5,000/100 ml count was surpassed about 90% of the time; and for those fields with corn stubble, this value was exceeded 100% of the time. Coliform counts were greater than 20,000/100 ml only about 10% of the time for the fields with permanent cover, but exceeded this value about 75% to 100% of the time when only minimum ground cover was maintained.

Snowmelt runoff should be some of the better surface water which would be added to a watercourse. The fact that snowmelt runoff has total

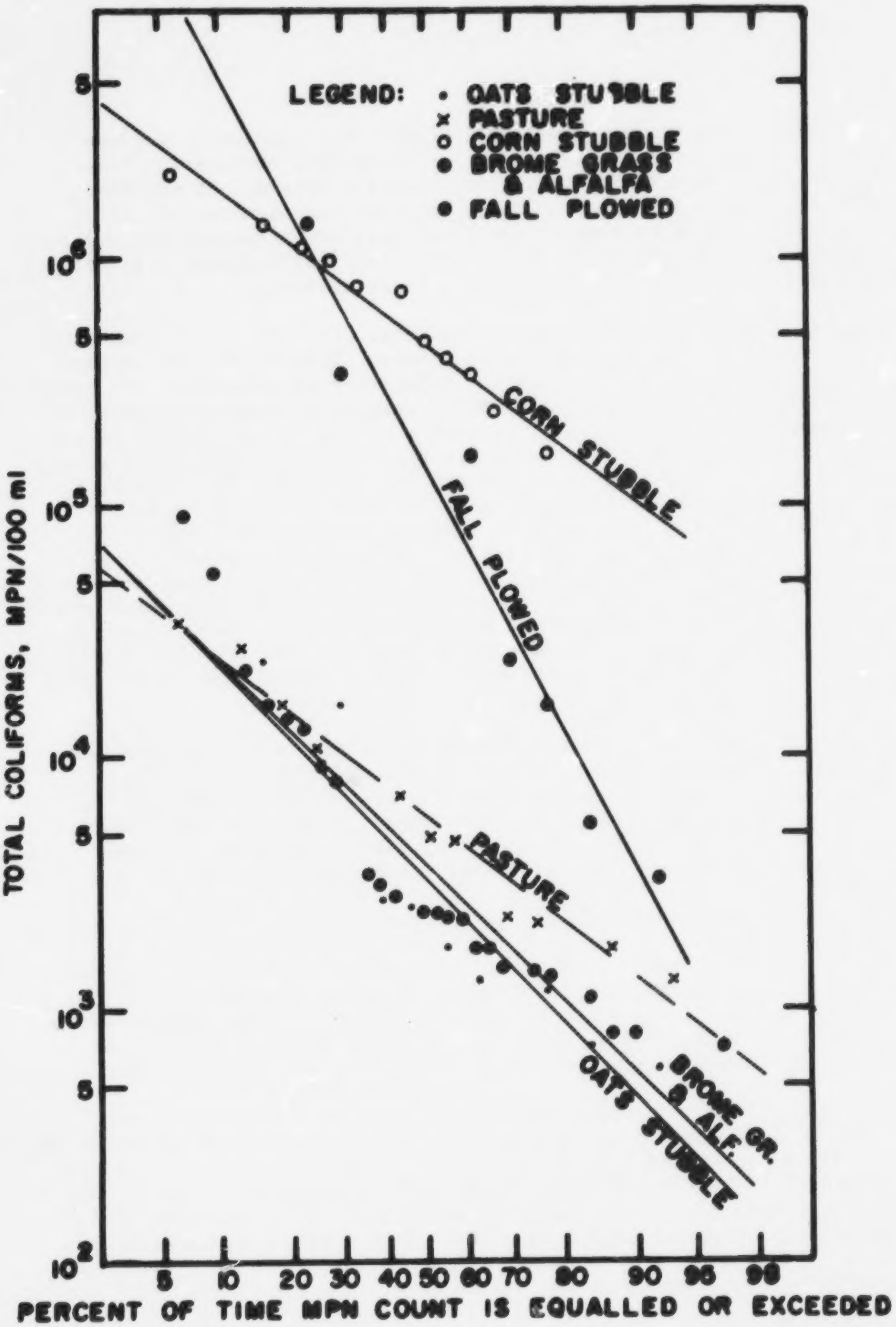


FIGURE 20.–Total coliforms in snowmelt runoff.

coliform counts which are normally higher than the total coliform water quality criteria may not be too important, because the beneficial uses vary for the individual surface waters. It may mean, however, that the limits for total coliform organisms should be reexamined. Because some of the total coliform organisms are commonly found on plants and the soil, the potential health hazard does not appear to be adequately reflected in these criteria.

Figure 21 shows regression lines for fecal coliform counts from snowmelt runoff for the different crop covers. Some variations between crop covers exist, but no distinct separation is apparent. One factor which tends to remove any distinction because of crop cover would be the common practice of pasturing cattle on most of the fields in the fall. Certainly this practice would be expected to affect the level of fecal coliforms present in the runoff. Referring to Table 9, it would appear that the critical level for fecal coliform organisms is 2000/100 ml during the time that snowmelt runoff would occur. The limits established for recreation and irrigation would not normally be enforced when snowmelt runoff was occurring. This level was exceeded less than 10% of the time for snowmelt runoff from fields which had oats stubble, corn stubble, or were fall plowed; and it was exceeded 20% to 40% of the time for pasture and hayland. The greater densities from the pasture and hayfields were attributed to the additional time that cattle were pastured on these sites.

Figure 22 exhibits the regression lines for the frequency of fecal streptococcus occurrence for the various crop covers for snowmelt runoff. All the lines have similar slopes and the runoff from the sites with minimum ground cover show higher densities. The relative positions of the regression lines with respect to each other are definite, but reasons for the placements are not apparent.

The densities of total coliform, fecal coliform, and fecal streptococcus organisms in rainfall runoff from cultivated fields are shown in Figure 23. The data for the total coliform and fecal streptococcus plots provide nearly parallel regression lines and some of the data points are identical. The data for the fecal coliform organisms result in a plot somewhat lower. This is as expected because the fecal coliforms represent only a portion of the total coliforms.

Discharges to a watercourse which have total coliform counts of 1,000 to 5,000 per 100 ml and/or fecal coliform levels of 200 to 2,000 per 100 ml can be considered as sources of pollution (See Table 9). Figure 23 indicates that these levels are exceeded about 90% of the time, or more, for total coliforms and 65% to 90% of the time when fecal coliforms are considered. These data suggest that runoff from agricultural lands may at times be a significant source of pollution for the surface waters of the state.

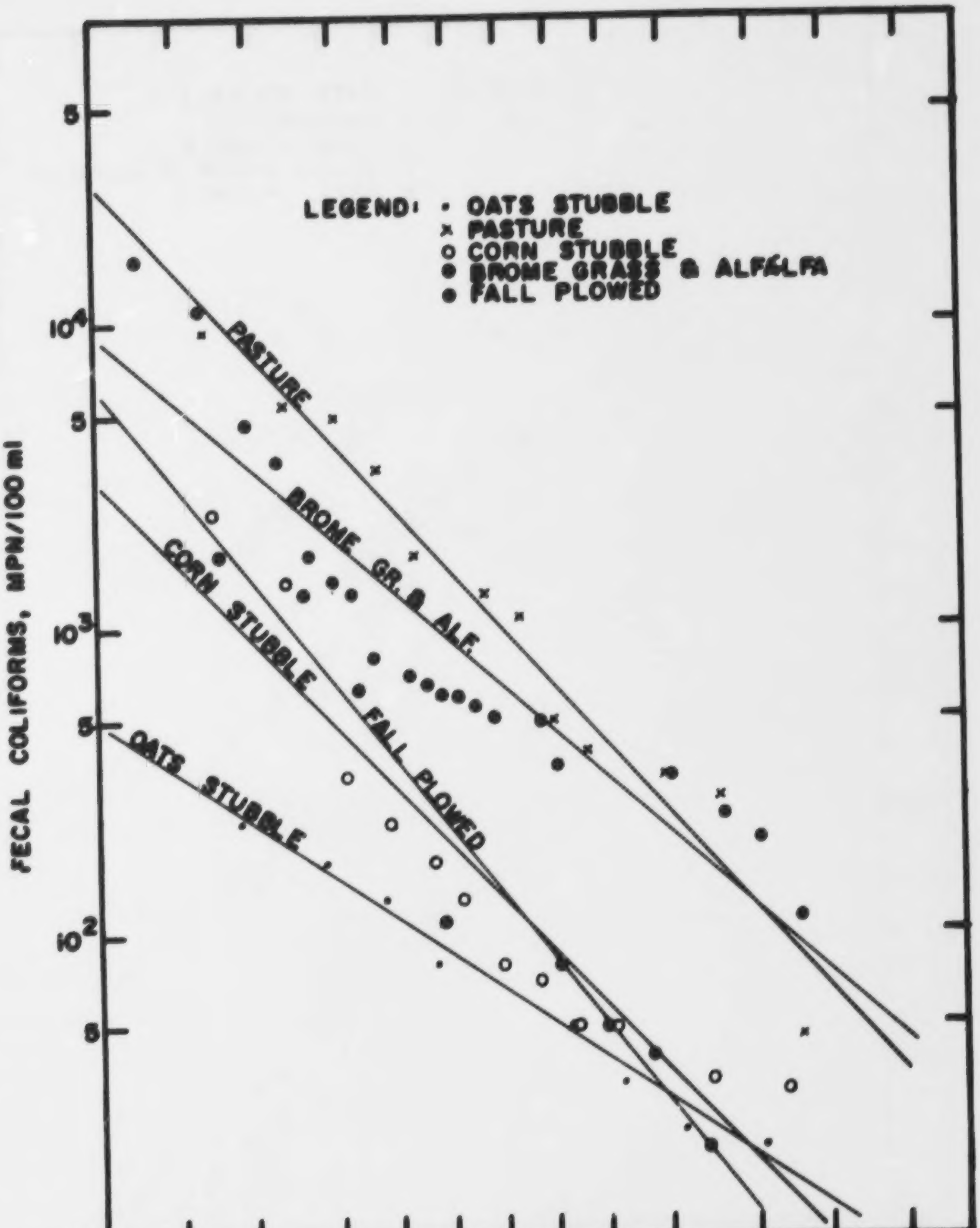


FIGURE 21.—Fecal coliforms in snowmelt runoff.

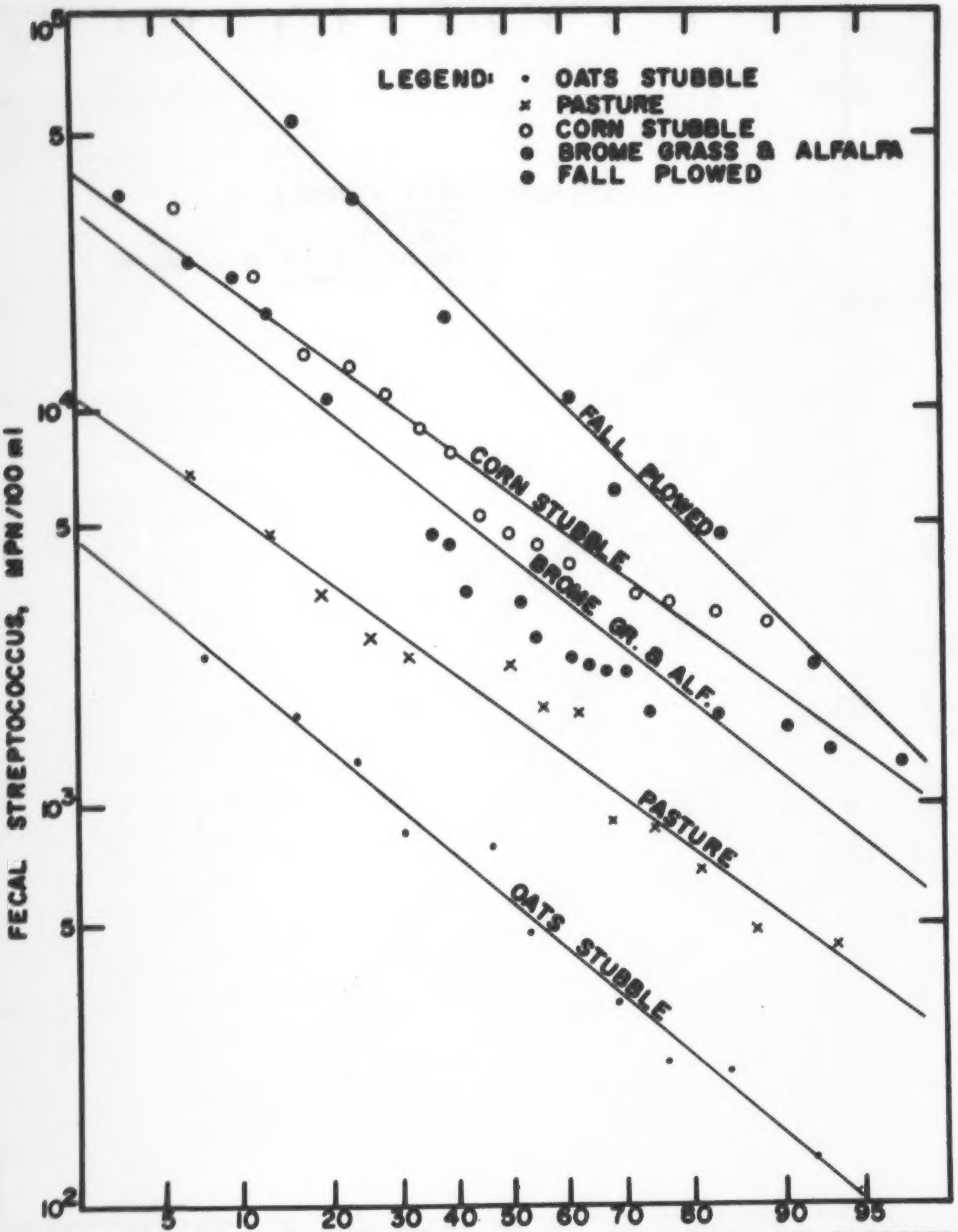


FIGURE 22.-Fecal streptococcus in snowmelt runoff.

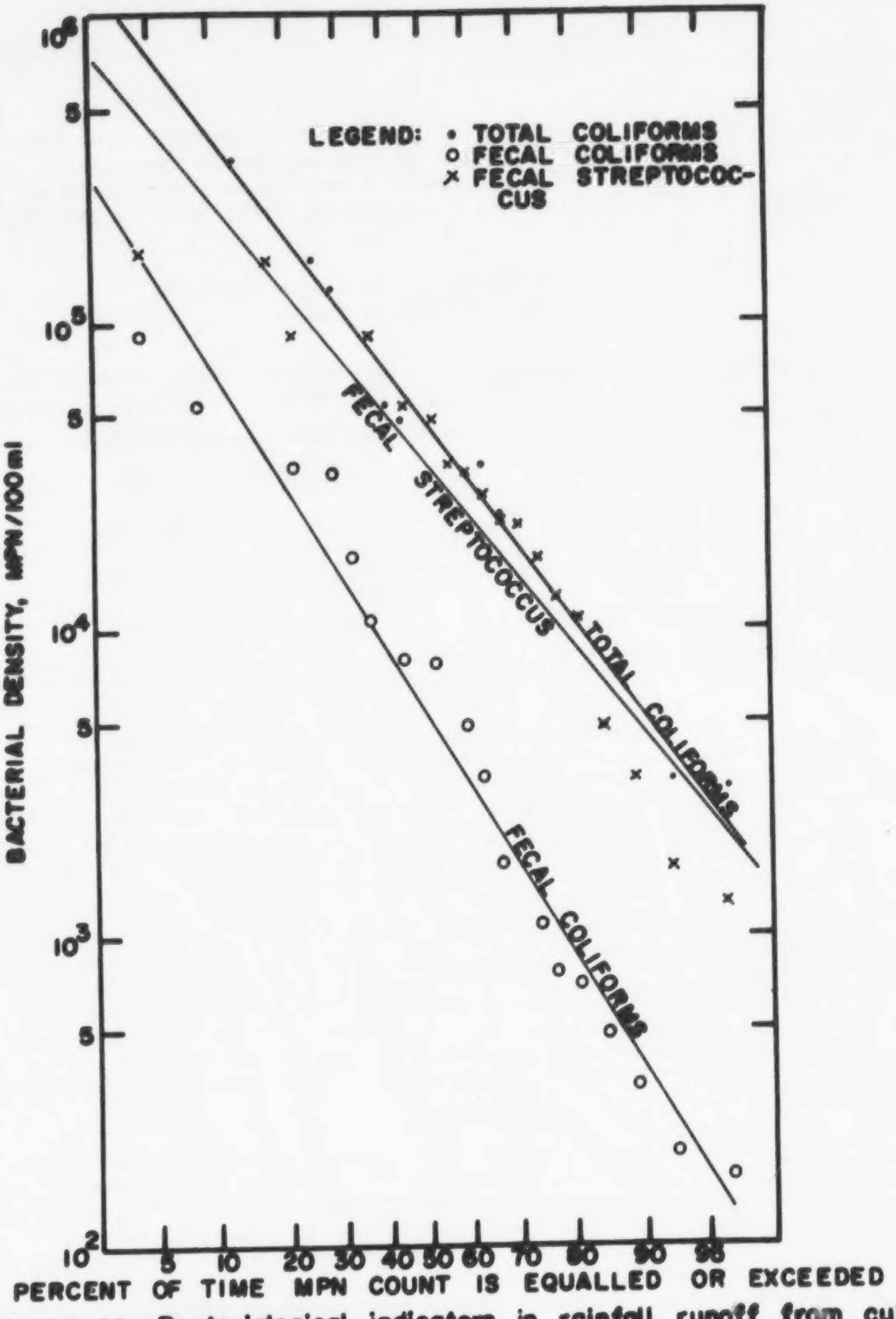


FIGURE 23.-Bacteriological indicators in rainfall runoff from cultivated fields.

Lack of rainfall runoff from uncultivated fields resulted in an insufficient amount of data on which to base any conclusions. These data are shown in Table 10 and generally seem to indicate levels of organisms which could cause the water quality criteria to be exceeded.

TABLE 10. - Bacteriological Data from Rainfall Runoff on Uncultivated Fields

Site	Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
3	7/28/72	161,000	790	161,000
4	7/28/72	161,000	330	161,000
7	5/29/72	54,000	4,600	17,200
7	7/28/72	1,610,000	161,000	91,800

Summarizing the bacteriological data, it would appear that runoff waters have indicator organism counts which frequently exceed the bacteriological limits established by water quality standards. Addition of these runoff waters to a watercourse can cause degradation and be construed as pollution. The actual health hazard has not been determined, and should be considered in the light of the FC/FS ratios as well as just total and fecal coliform densities.

Total coliform densities are usually somewhat greater than the fecal coliform or fecal streptococcus levels. This relationship would probably be influenced by the coliform organisms which are found in the soil and it does not necessarily indicate fecal contamination or the presence of pathogenic organisms. In the past, it has frequently been found that polluted water resulting from farm animal discharges give total coliform and fecal streptococcus densities of the same order of magnitude (69).

It would appear that the current water quality standards should recognize the quality of agricultural runoff as providing a basis for water quality improvement. Agricultural runoff is a nonpoint source of water pollution; and consequently, it is virtually uncontrollable. Criteria which establish water quality parameters at levels less than the levels present in agricultural runoff or other nonpoint sources may be unrealistic. Perhaps a better approach would be to establish the water quality criteria at levels which reflect the quality of streams from agricultural areas and then attempt to improve the quality of the runoff. Subsequent sampling would establish any improvements in agricultural runoff quality which could be obtained.

Pesticides

Concern over degradation of the environment by pesticides has developed in recent years. Organochlorine insecticides have been outlawed in Hungary. Other countries, including the United States, have expressed their concern by restricting or banning certain pesticides.

The wide acceptance and usage of some insecticides and herbicides has resulted in their becoming virtually ubiquitous. Determinations for these pesticides are often positive even when there has been no known usage of the chemicals in the area. Some investigations report the travel of pesticides in the atmosphere and also the finding of these compounds in rainfall (51).

The United States Public Health Service conducted a study to determine the distribution of chlorinated hydrocarbon insecticides in the major drainage basins of the United States and collected water samples for analysis from 41 states. They found widespread distribution of dieldrin, endrin, DDT, and DDE (58). Samples in the Brookings County, S. Dak. study were also investigated for these four insecticides which the USPHS has found to be widespread. In addition, analyses were made for aldrin, lindane, heptachlor, heptachlor epoxide, DDD, atrazine, and methoxychlor.

Because most of these pesticides are relatively insoluble in water, it was quite likely that they might be associated with the soil particles in runoff. Consequently, sediment or mud samples were investigated when samples could be obtained. Only small amounts of soil were present in snowmelt runoff. Therefore, only filtered runoff samples were used for pesticide determinations during snowmelt. If enough soil was washed from a site when rainfall runoff occurred, mud samples as well as filtered water samples were examined.

Data for all the pesticide samples were evaluated together without any designation regarding the site from which the sample was obtained. The results of the pesticide analyses are shown in Tables 11 and 12. In general, the level of all the pesticides present in the runoff seems to be quite low, and the majority of the concentrations were below the analytical test limits.

Table 11 presents the findings for 75 filtered samples. These 75 samples include the filtered snowmelt samples and the filtered rainfall runoff samples. The vast majority of the data are below the analytical test limits and all values are less than one part per billion (ppb). These results agree with the USPHS study which reported that

TABLE 11. - Number of Samples Grouped in Ranges of Pesticide Concentrations for Filtered Runoff Samples

Concentration (ppb)	Aldrin	DDT	DDE	DDD	Atrazine, Diedrin, Lindane, Heptachlor, Heptachlor Epoxide Endrin, Methoxychlor
Below limits*					
Snowmelt	49	44	48	44	49
Rainfall	24	24	15	25	26
.05 - .09		Does not apply*		Does not apply*	
Snowmelt	0		0		0
Rainfall	1		3		0
.10 - .30					
Snowmelt	0	4	1	5	0
Rainfall	0	2	8	1	0
.31 - .50					
Snowmelt	0	1	0	0	0
Rainfall	0	0	0	0	0
.51 - .75					
Snowmelt	0	0	0	0	0
Rainfall	1	0	0	0	0
Total	75	75	75	75	75

* Analytical test limits: 0.05 ppb for Aldrin, DDE, Dieldrin, Lindane, Heptochlor, Heptachlor Epoxide, and Endrin. 0.10 ppb for DDT, DDD, Atrazine and Methoxychlor.

all the pesticide concentrations were less than one ppb (58). A distribution of the pesticide concentrations for the sediment samples is shown in Table 12. A total of 24 samples were collected, and the majority of the samples had concentrations of pesticides which were less than the analytical test limits.

Chemical and Physical Characteristics

The basic project objectives were to find the concentrations of the runoff's constituents, and also to determine the total contribution of these constituents on an annual basis. The chemical and physical characteristics of runoff are related to the drainage area, the nature of the runoff and the land management practices.

Two broad categories of runoff were observed. They resulted from snowmelt runoff and rainfall runoff. Runoff from snowmelt generally had a low suspended solids content, often less than 20 mg/l, and exhibited a characteristic yellow-tan color. Snowmelt runoff typically started slowly and reached a peak during the early afternoon hours when the effect of the sun's rays was most pronounced.

Rainfall runoff generally had a much higher suspended solids content than snowmelt runoff, sometimes reaching the several thousand mg/l range. It too showed color; but usually not of the same intensity as snowmelt runoff, particularly if allowed to settle. Runoff resulting from rainfall tended to be a more violent event of much shorter duration. The runoff hydrograph may have reached its peak only a few minutes after runoff began. Runoff then continued to taper off until the event was finished.

The dissolved material present was fairly uniform as measured by the specific conductance determination. Values ranged from 69 to 352 µmhos/cm for the two year study. Median specific conductance for snowmelt runoff was 124 µmhos/cm. The range of specific conductance for rainfall runoff was wider being 45 to 538 µmhos/cm. The median specific conductance value was 210 µmhos/cm. A general observation would be that the quality of rainfall runoff as measured by specific conductance, is more variable than snowmelt runoff.

The mean concentrations of some runoff parameters are presented in Table 13. These are averages of concentrations and are not weighed with respect to flow. Sites No. 1, 2, 8 and 9 were combined to give an indication of the runoff characteristics from cultivated land, Site No. 7 represents the pasture, and Sites No. 3 and 4 yielded data for the land use category of alfalfa and brome grass. Mean concentrations of all the runoff parameters are broken down by site in the Appendix.

Note the prominent differences between rainfall and snowmelt runoff data. In all cases, the number of snowmelt events exceeds the number

TABLE 12. - Number of Samples Grouped in
Ranges of Pesticide Concentrations for Sediment Samples

Concentration (ppb Dry Wt.)	Aldrin	DDT	DDE	Atrazine	Dieldrin, DDD, Lindane, Heptachlor, Heptachlor Epoxide Endrin, Methoxychlor
Below limits*	11	20	15	23	24
5.0 - 9.9	2	*	2	0	0
10 - 15	3	1	3	0	0
16 - 25	0	2	3	0	0
26 - 50	1	1	0	0	0
51 - 75	1	0	0	0	0
76 - 100	3	0	0	0	0
100 - 150	0	0	0	0	0
150 - 200	1	0	1	0	0
200 - 250	0	0	0	0	0
250 - 300	2	0	0	0	0
> 300	0	0	0	1	0
Total	24	24	24	24	24

*Analytical test limits: 5.0 ppb for Aldrin, DDE, Dieldrin, Lindane, Heptachlor, Heptachlor Epoxide, and Endrin.
10.0 ppb for DDT, DDD, and Methoxychlor
100 ppb for Atrazine.

TABLE 13. - Mean Concentrations of Runoff Parameters by Land Use

Parameter	Cultivated Land		Crop Cover Pasture		Alfalfa & Brome Grass	
	Snow	Rain	Snow	Rain	Snow	Rain
Total Residue, mg/l	187	1241	150	222	134	108
Suspended Solids, mg/l	51	1021	18	38	42	40
Total Phosphorus, mg/l	0.44	1.05	0.67	0.49	0.43	0.35
Nitrate, mg/lN	1.0	1.5	0.9	0.4	0.8	0.3
Total Kjeldahl Nitrogen mg/lN	2.1	2.6	3.3	1.7	2.8	0.8
COD, mg/l	49	148	69	49	62	22
No. Samples	44	28	16	2	31	2

of rainfall events. Few rainfall runoff events occurred on uncultivated lands. For these sites, the uncultivated fields averaged less than one rainfall runoff event per site per year.

Another notable comparison between rainfall and snowmelt runoff is the difference in the concentration level which occurred for some of the parameters. This difference is particularly true with respect to solids data. A substantial change in magnitude is apparent when the mean suspended solids for cultivated land during rainfall runoff is compared to its counterpart for snowmelt runoff, for example. Comparing the average mean values of 51 mg/l of suspended solids with 1,021 mg/l reveals about a 20 fold increase for rainfall runoff.

The magnitude of the suspended solids variation varied from use to use, but this increase was especially conspicuous for the cultivated fields. Apparently, runoff from rainfall has better quality if it results from permanent grassland.

The uncultivated sites (Sites No. 3, 4, and 7) show relatively little change in parameter concentrations when comparing snowmelt to rainfall runoff. In fact, some of the mean concentrations are much less for snowmelt. The nitrogen and phosphorus levels for uncultivated sites tended to be higher for snowmelt events than for rainfall runoff. Just the opposite was true for the cultivated sites. Freezing and thawing help rupture organic molecules which produces material more easily dissolved or carried in the runoff. Because more organic material was available on the noncultivated sites, they often had snowmelt nutrient levels higher than the cultivated fields. Rainwater does not remain on the fields as long as water resulting from melted snow. Any increase in nutrient levels for rainfall runoff was probably associated with suspended matter washed from the fields. This would account for the increase in nutrients from rainfall runoff for the cultivated lands.

Nutrient levels are of interest because of the continuing emphasis on eutrophication problems. Levels of nitrogen and phosphorus which have often been quoted as causing nuisance algal growths in lakes are 0.01 mg/l of inorganic phosphorus and 0.3 mg/l of inorganic nitrogen. It is believed that these particular levels were first quoted by Sawyer (21). Total phosphorus was measured during this study instead of inorganic phosphorus because in a lake's ecosystem there is a continuing conversion from one phosphorus form to another. Even organic phosphorus which is bound up in the bottom sediments of a lake may later be used to increase biological activity (70). In a recent article, Loehr also agrees with this concept as he states that: "The phosphorus of concern to environmental quality is associated with that adsorbed on sediment and with the interchange of phosphorus from bottom deposits in bodies of waters with the upper waters" (71). This same reasoning applies to the nitrogen values although some differentiation in nitrogen forms was made.

All mean concentrations of nitrate alone equal or exceed the 0.3 mg/l level, sometimes reaching 1.5 mg/l. Adding ammonia to the nitrate amplifies the inorganic nitrogen contribution of runoff waters. Ammonia had a nearly constant level, varying only from 0.1 to 0.4 mg/l N for all rainfall events. Ammonia was not measured for snowmelt runoff, but was included with organic nitrogen in the total kjeldahl nitrogen determination.

Phosphorus data show concentrations many times in excess of 0.01 mg/l. Even soluble phosphorus levels in snowmelt runoff were in the 0.2 to 0.3 mg/l P range and consequently, practices aimed at retaining the soil, such as sediment traps, would not greatly decrease the phosphorus load discharged from a field.

The above nitrogen and phosphorus levels suggest that agricultural runoff may be an important contributing factor to lake eutrophication. Further expenditures for advanced treatment for municipal and industrial wastewater plants may be superfluous if a significant reduction in lake eutrophication is the intention of such expenditures and agricultural runoff is not controlled.

Table 14 gives the total yearly contributions of the runoff constituents in lb/acre/yr. The annual soil loss for each site did not exceed 1/2 ton/acre/yr, (See Appendix). The average annual loss for cultivated land was less than 300 lb/acre/yr. This is in sharp contrast to some long-term reported values of Missouri and Ohio studies. Reported cultivated field soil losses from a small plot study in Missouri were from 2.78 to 19.72 ton/acre/yr (8). Soil losses from the 1.5 acre fields in Ohio averaged 2.16 ton/acre/yr. The maximum annual loss occurred on corn fields at a rate of 7.70 ton/acre/yr (5).

Agricultural experts seek to establish soil conservation practices to allow a tolerable erosion of less than 3 to 4 ton/acre/yr (72). This would seem to indicate that the erosion rate is satisfactory for the sites under consideration. Yet most of the cultivated sites exhibit some of the common signs associated with soil erosion such as sub-soil protrusion on the ridges, silting in road ditches, some gullying, and rock outcrops. The land owner of two of the cultivated sites is presently considering a permanent grass cover to decrease his soil losses.

Climatic factors undoubtedly provide at least a partial explanation for the differences in soil losses between this study and the two studies mentioned above. Both Ohio and Missouri annually average about twice the precipitation and about ten times the runoff as the research sites evaluated in this study (73). Differences in rainfall intensity, amount of snowmelt runoff, soil type, slope, and farming practices would be considerations. Also, the studies may not be comparable because of the size of the research areas being investigated. Small 90 ft

TABLE 14. - Yearly Runoff Contributions of Runoff Parameters by Land Use

Parameter (lb/acre/yr)	Crop Cover Cultivated Land	Pasture	Alfalfa & Brome Grass
Total Residue	298	51.9	28.9
Suspended Solids	255	10.5	3.6
Total Phosphorus	0.27	0.22	0.09
Nitrate - N	0.33	0.36	0.21
Total Kjeldahl Nitrogen	0.81	1.00	0.65
COD	43	25	12

long plots and 1.5 acre areas may tend to measure soil movement instead of actual soil losses.

A pictorial summary of all the runoff for both years of Phase II is expressed in Figure 24. The number beneath each pie chart, with the exception of the area chart, represents the total quantity contributed during the two year study. For example, 23, 687 lb of suspended solids was washed off the seven sites in both years.

The total runoff area was divided into cultivated land, pasture, and alfalfa and brome grass. Sites No. 1, 2, 8, and 9 were under cultivation and the summation of their areas was 56.3% of the total research area. In addition, Site No. 7 was the pastured area, and Sites No. 3 and No. 4 comprised the alfalfa and brome grass segment.

Some interesting observations were made. One of the most striking was the relationship between rainfall runoff and its total contribution. While rainfall runoff comprised only 32.2% of the total runoff, it was responsible for 93.7% of the suspended matter and 61.8% of the COD lost in the runoff. Thus, almost all of the soil loss was caused by only about one-third of the runoff.

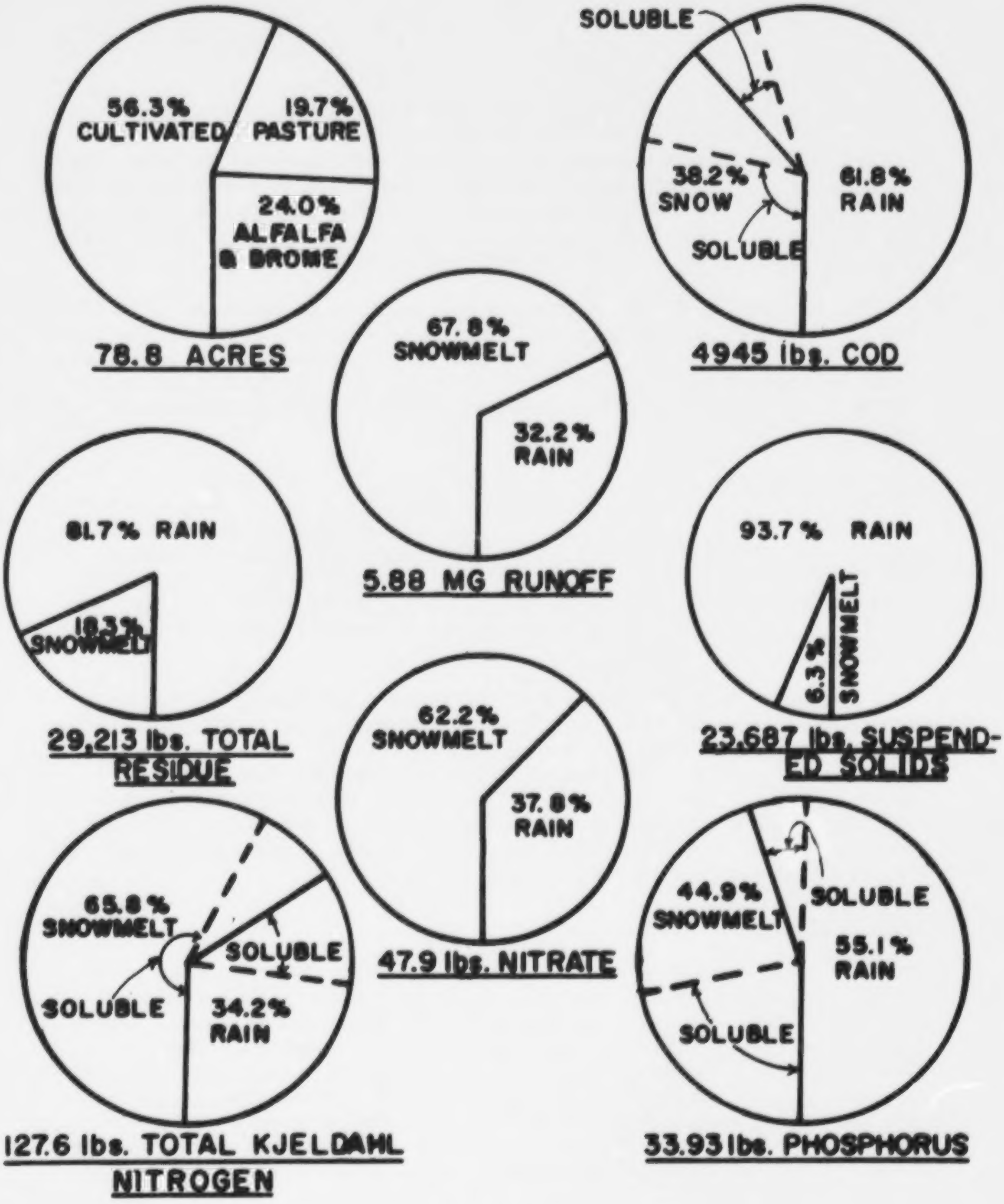


FIGURE 24.- Breakdown of total runoff contributions for 1971 and 1972.

It would appear that pollution from agricultural runoff would be effectively reduced if rainfall runoff was eliminated, or if complete sedimentation occurred. Yet, the nutrient contributions indicate just the opposite. Snowmelt runoff accounted for 65.8% of the total kjeldahl nitrogen, 62.2% of the nitrate, and 44.9% of the phosphorus lost during the two years. Important quantities of nutrients would still be lost annually even if all rainfall runoff was eliminated.

A large proportion of the nutrients was found to be soluble. All of the nitrate, 69% of the total kjeldahl nitrogen, and 27.5% of the phosphorus were independent of any sediment. Soil conservation practices could be implemented to hold soil losses to some acceptable minimum, but such practices could not be construed as limiting nutrients as well.

Soluble Fraction

The data in Table 15 represent the mean percentages of chemical oxygen demand, phosphorus, or total kjeldahl nitrogen which were soluble. For example, 75.1% of the COD contributed from Site No. 1 during the snowmelt runoff events of 1971 was soluble. During 1971 rainfall runoff was recorded only on Site No. 8, and snowmelt runoff did not occur on Site No. 9 during 1972.

As a general observation, most of the three constituents are soluble for snowmelt runoff, and a substantial percentage of rainfall runoff was also soluble. However, the amount of soluble components diminishes for rainfall runoff. In fact, most of the data for the cultivated lands (Site No. 1, 2, 8 and 9) indicate that major portions of the constituents were associated with the sediment. The sites which are permanently covered with grass continued to have a high percentage of the three parameters remaining soluble.

Soil - Losses

This study is unique in that published data from other studies which evaluated soil-losses in surface runoff from melting snow could not be found. The total soil-losses were much less than expected, especially when considering the universal soil-loss equation. The present "universal" soil loss equation did not appear to be suitable for estimating the potential of water pollution from agricultural lands for the geographic area studied. Results from future studies in other areas with dissimilar climatic conditions will be required before the adequacy of the universal soil-loss equation for larger areas can be evaluated.

TABLE 15. - Soluble Fraction of COD, Phosphorus and TKN of Snowmelt and Rainfall Runoff from Research Sites

	Mean Percentage Snowmelt - 1971			Mean Percentage Snowmelt - 1972			Mean Percentage Rainfall - 1971			Mean Percentage Rainfall - 1972		
Site	COD*	P*	TKN*	COD	P	TKN	COD	P	TKN	COD	P	TKN
1	75.1	72.8	75.9	90.9	97.7	100.0	-	-	-	48.8	56.1	69.5
2	75.1	69.9	82.8	48.1	72.4	82.1	-	-	-	7.4	12.6	16.3
3	67.3	43.1	72.2	54.4	34.2	67.1	-	-	-	72.7	53.3	87.5
4	72.0	48.6	79.5	52.6	27.2	67.0	-	-	-	90.9	67.5	87.5
7	67.8	50.0	77.6	61.3	52.0	70.2	-	-	-	63.9	64.1	73.3
8	81.8	62.2	89.4	55.5	47.5	72.8	37.9	21.1	31.1	26.7	24.9	41.9
9	82.1	66.4	98.2	-	-	-	-	-	-	46.2	43.3	57.9

* COD - Chemical oxygen demand
P = Phosphorus
TKN - Total kjeldahl nitrogen

SECTION IX

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SECTION X

APPENDICES

Page

A. Chemical and Physical Quality Data 97

B. Bacteriological Quality Data 123

C. Pesticide Data 137

D. Mean Concentrations of Parameters 143

E. Annual Contributions 148

APPENDIX A

Chemical and Physical Quality Data

Site No. 1
Area = 7.18 acres
Cover: Corn stubble and oats

Table A1. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1970

Characteristic*		Mar 23	Mar 31	Apr 1	Apr 2	Apr 4	Apr 5	May 31	June 15B
Volume (gal)		1,000	550	7,100	9.700	13,600	600	29,800	-
pH- units		7.4	7.4	7.5	7.4	7.4	7.5	6.9	-
Specific Conductance (μ mhos/cm)		125	150	125	100	96	170	46	-
Suspended Solids		140	38	242	284	584	92	15,200	3,330
Total Residue		302	179	293	418	890	315	22,100	4,810
5-day BOD		12	9	10	10	11	17	9	-
COD	Raw	105	56	73	82	125	91	1,780	610
	Soluble	70	48	60	53	74	93	25	-
Total Kjeldahl	Raw	3.8	2.5	2.5	3.0	2.7	4.1	4.5	2.6
Nitrogen	Soluble	2.5	2.0	2.2	1.9	2.1	3.0	1.1	0.6
Total Phosphorus	Raw	0.68	0.27	0.40	0.41	0.95	1.13	4.30	2.20
as P	Soluble	0.36	0.18	0.24	0.12	0.20	0.68	0.35	0.08
Nitrate	Raw	1.4	1.8	1.3	1.9	0.8	1.5	2.1	0.6
as N	Soluble	1.6	2.1	1.6	2.0	0.8	1.5	2.1	0.6

Table A1 (continued)

Characteristic*		Mar 23	Mar 31	Apr 1	Apr 2	Apr 4	Apr 5	May 31	June 15B
Ammonia	Raw	0.75	0.96	0.75	0.77	0.58	0.98	0.84	0.29
	Soluble	1.17	0.96	1.00	1.20	1.35	1.75	1.26	-
Total Nitrogen		5.2	4.3	3.8	4.9	3.5	5.6	6.6	3.2

* All concentrations in milligrams per liter except as noted

Site No. 2
Area = 8.77 acres
Cover: corn stubble and oats

Table A2. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings, South Dakota - 1970

Characteristic*		Mar 23	Mar 31	Apr 1	Apr 2	Apr 4	May 31	June 15A
Volume (gal)		700	100	6,400	7,200	6,900	57,500	725
pH-units		7.4	7.4	7.4	7.4	7.5	6.9	6.8
Specific Conductance (µ mhos/cm)		146	160	130	110	114	48	27
Suspended Solids		38	6	17	38	71	7,500	1,200
Total Residue		187	168	128	275	195	8,610	1,360
5-day BOD		16	15	11	-	16	8	7
COD	Raw	82	79	62	80	75	980	202
	Soluble	74	84	86	62	83	38	23
Total Kjeldahl Nitrogen	Raw	3.7	3.3	2.8	2.4	3.4	4.8	1.5
	Soluble	2.7	0.7	2.6	2.2	2.4	1.0	0.9
Total Phosphorus as P	Raw	0.66	0.42	0.36	0.47	0.60	0.54	1.17
	Soluble	0.34	0.39	0.27	0.17	0.36	0.07	0.18
Nitrate as N	Raw	1.4	1.0	0.8	0.3	0.6	1.8	0.7
	Soluble	1.2	1.1	1.2	1.7	0.6	1.7	0.6

Table A2 (continued)

Characteristic*		Mar 23	Mar 31	Apr 1	Apr 2	Apr 4	May 31	June 15A
Ammonia	Raw	0.87	1.02	0.72	0.54	0.69	0.91	0.92
	Soluble	1.25	1.11	1.27	1.35	1.67	0.92	0.47
Total Nitrogen		5.1	4.3	3.6	2.7	4.0	6.5	2.1

*All concentrations in milligrams per liter except as noted.

Site No. 3
Area - 10.12 acres
Cover: Brome grass & alfalfa

Table A3. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings, South Dakota - 1970

Characteristic*		Mar 23	Apr 1	Apr 2
Volume (gal)		5,600	22,800	1,100
pH-units		7.6	7.7	7.6
Specific Conductance (μ mhos/cm)		208	202	153
Suspended Solids		31	34	75
Total Residue		227	225	222
5-day BOD		18	16	14
COD	Raw	129	97	103
	Soluble	121	127	93
Total Kjeldahl Nitrogen	Raw	6.1	5.1	4.0
	Soluble	3.5	3.1	3.1
Total Phosphorus as P	Raw	0.72	0.60	0.48
	Soluble	0.08	0.30	0.17
Nitrate as N	Raw	1.2	0.2	0.2
	Soluble	1.2	0.3	0.3

Table A3 (continued)

Characteristic*		Mar 23	Apr 1	Apr 2
Ammonia	Raw	1.84	1.53	1.09
	Soluble	2.57	1.10	1.87
Total Nitrogen		7.3	5.3	4.2

*All concentrations in milligrams per liter except as noted.

Site No. 4
Area = 8.77 acres
Cover: Brome grass & alfalfa

Table A4. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings, South Dakota - 1970

Characteristic*		Mar 23	Apr 1	Apr 4
Volume (gal)		120	180	900
pH-units		7.6	7.8	7.7
Specific Conductance (µ mhos/cm)		202	225	178
Suspended Solids		21	24	19
Total Residue		223	258	230
5-day BOD		21	18	-
COD	Raw	131	131	105
	Soluble	130	140	87
Total Kjeldahl Nitrogen	Raw	5.6	5.6	4.5
	Soluble	2.4	1.2	2.1
Total Phosphorus as P	Raw	0.94	0.68	1.35
	Soluble	0.62	0.37	0.77
Nitrate as N	Raw	0.9	0.3	0.1
	Soluble	1.1	0.4	0.2

Table A4 (continued)

Characteristic*		Mar 23	Apr 1	Apr 4
Ammonia	Raw	1.37	1.52	1.16
	Soluble	1.16	1.12	1.26
Total Nitrogen		-	-	-

*All concentrations in milligrams per liter except as noted.

Site No. 1
Area = 7.18 acres
Cover: Oat stubble and oats

Table A5. - Chemical and Physical Quality Characteristics of Agricultural Runoff
Brookings County, South Dakota - 1971

Characteristic*		Feb.16	Feb 17	Feb 18	Feb 25	Feb 26	Mar 11	Mar 12	Mar 13
Volume (gal)		1,900	9,100	2,400	7,200	6,800	6,200	18,200	6,300
Specific Conductance (µ mhos/cm @ 25°C)		190	170	179	106	107	97	107	103
Suspended Solids		77	25	11	18	5	27	90	157
Total residue		220	186	171	132	102	93	202	260
COD	Raw	51	34	32	28	26	23	44	38
	Soluble	25	26	32	28	13	32	24	12
Total kjeldahl nitrogen	Raw	1.4	2.0	1.0	0.9	0.9	1.3	1.7	0.9
	Soluble	1.1	1.1	1.0	0.8	0.5	1.2	1.0	0.7
Total phosphorus as P	Raw	0.98	0.55	0.39	0.28	0.25	0.28	0.41	0.61
	Soluble	0.82	0.48	0.38	0.21	0.18	0.17	0.26	0.26
Nitrate as N		1.0	0.6	0.5	0.5	0.3	0.5	0.3	0.2
Total nitrogen		2.4	2.6	1.5	1.3	1.2	1.8	2.0	1.1

*All concentrations in milligrams per liter except as noted.

Site No. 2
Area = 8.77 acres
Cover: Oat stubble and oats

Table A6. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1971

Characteristic*		Feb 16	Feb 17	Feb 18	Feb 25	Feb 26
Volume (gal)		2,000	7,900	2,100	6,100	5,000
Specific conductance (μ mhos/cm @ 25°C)		192	148	154	87	90
Suspended solids		63	45	17	14	5
Total residue		232	188	149	136	87
COD	Raw	51	36	36	28	20
	Soluble	27	27	30	25	15
Total kjeldahl nitrogen	Raw	1.6	1.2	1.1	1.3	1.0
	Soluble	1.6	1.4	1.0	0.6	0.6
Total phosphorus as P	Raw	0.93	0.40	0.30	0.22	0.18
	Soluble	0.70	0.30	0.27	0.13	0.09
Nitrate as N		1.0	0.4	0.3	0.3	0.4
Total nitrogen		2.6	1.6	1.4	1.6	1.4

*All concentrations in milligrams per liter except as noted.

Site No. 3
Area = 10.12 acres
Cover: Brome grass & alfalfa

Table A7. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1971

Characteristic*		Feb 16	Feb 17	Feb 18	Feb 25	Feb 26	Mar 10	Mar 11	Mar 12	Mar 13
Volume (gal)		144,000	80,300	2,300	37,800	3,100	30,500	33,100	25,000	8,000
Specific conductance (μmhos/cm @ 25°C)		99	129	177	82	122	107	117	117	136
Suspended solids		17	17	17	6	5	19	25	23	21
Total residue		129	130	155	92	131	110	145	130	102
COD	Raw	34	43	63	52	44	78	85	70	38
	Soluble	23	36	40	41	41	48	53	35	17
Total kjeldahl nitrogen	Raw	1.5	2.4	2.6	1.9	1.7	3.3	4.0	3.6	1.2
	Soluble	1.5	1.6	1.9	1.5	1.3	2.3	2.5	1.4	1.0
Total phosphorus as P	Raw	0.20	0.37	0.55	0.27	0.28	0.63	0.77	0.66	0.52
	Soluble	0.13	0.20	0.31	0.12	0.10	0.22	0.18	0.21	0.22
Nitrate as N		1.0	0.8	1.2	0.4	0.4	0.3	0.4	0.5	0.2
Total nitrogen		2.5	3.2	3.8	2.3	2.1	3.6	4.4	4.1	1.4

*All concentrations in milligrams per liter except as noted.

Site No. 4
Area = 8.77 acres
Cover: Brome grass & alfalfa

Table A8. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1971

Characteristic*	Feb 16	Feb 17	Feb 18	Feb 25	Feb 26	Mar 10	Mar 11	Mar 12	Mar 13
Volume (gal)	51,000	41,000	2,500	19,200	19,900	44,100	47,600	45,100	11,800
Specific Conductance (µmhos/cm @ 25°C)	98	125	178	69	94	107	101	112	115
Suspended solids	18	19	16	7	3	11	17	18	11
Total residue	105	126	161	87	156	110	109	116	94
COD Raw	43	43	63	36	34	72	68	66	28
Soluble	28	34	38	33	30	49	53	33	19
Total kjeldahl nitrogen Raw	1.6	1.9	2.5	1.3	1.3	2.8	3.5	3.5	1.3
Soluble	1.6	1.8	1.6	1.0	1.2	2.4	2.5	1.6	1.1
Total phosphorus as P Raw	0.21	0.36	0.42	0.18	0.16	0.52	0.72	0.62	0.46
Soluble	0.13	0.17	0.23	0.07	0.09	0.26	0.23	0.22	0.28
Nitrate as N	1.1	1.0	1.1	0.6	0.6	0.4	0.4	0.4	0.1
Total nitrogen	2.7	2.9	3.6	1.9	1.9	3.2	3.9	3.9	1.4

*All concentrations in milligrams per liter except as noted.

Site No. 7
Area = 15.51 acres
Cover: Grassland - pastures

Table A9. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1971

Characteristic*		Feb 16	Feb 17	Feb 18	Feb 25	Feb 26	Mar 10	Mar 11	Mar 12	Mar 13
Volume (gal)		118,000	117,000	6,200	46,600	15,600	19,800	127,000	90,000	9,800
Specific conductance (µmhos/cm @ 25°C)		121	114	252	115	116	151	137	148	229
Suspended solids		37	17	23	18	4	17	23	28	23
Total residue		157	113	248	119	120	143	127	148	208
COD	Raw	55	53	121	62	48	74	76	86	85
	Soluble	39	36	76	45	44	50	55	41	48
Total kjeldahl nitrogen	Raw	2.3	2.7	5.6	2.5	1.9	3.1	3.6	4.9	4.1
	Soluble	2.3	2.2	5.6	1.6	1.8	2.4	2.5	2.0	2.9
Total phosphorus as P	Raw	0.36	0.40	0.97	0.53	0.31	0.72	0.86	1.04	1.43
	Soluble	0.27	0.20	0.41	0.26	0.21	0.34	0.33	0.38	0.63
Nitrate as N		1.2	1.0	2.4	0.6	0.6	0.4	0.4	0.4	0.3
Total nitrogen		3.5	3.7	8.0	3.1	2.5	3.5	4.0	5.3	4.4

*All concentrations in milligrams per liter except as noted.

Site No. 8
Area = 18.68 acres
Cover: Corn stubble and oats

Table A10. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1971

Characteristic*		Feb 16	Feb 17	Feb 18	Feb 25	Feb 26	Mar 10	Mar 11	Mar 12	Mar 13
Volume (gal)		131,000	137,000	3,200	50,800	33,300	13,000	232,000	218,000	52,600
Specific Conductance (µmhos/cm @ 25°C)		117	127	209	120	111	121	113	121	176
Suspended solids		73	32	75	13	2	7	41	58	14
Total residue		185	140	203	143	82	137	153	150	153
COD	Raw	53	40	61	56	44	83	64	76	40
	Soluble	35	31	38	45	42	72	55	70	36
Total kjeldahl nitrogen	Raw	2.0	2.2	2.4	1.7	1.7	4.6	3.0	1.7	1.7
	Soluble	2.0	2.0	2.0	1.3	1.8	3.6	2.4	2.9	1.7
Total phosphorus as P	Raw	0.51	0.39	0.56	0.30	0.21	0.46	0.41	0.40	0.34
	Soluble	0.35	0.32	0.50	0.18	0.19	0.27	0.16	0.05	0.20
Nitrate as N		0.9	0.9	1.6	0.8	0.7	0.6	0.5	0.5	0.6
Total nitrogen		2.9	3.1	4.0	2.5	2.4	5.2	3.5	2.2	2.3

Table A10. - Continued

Characteristic*	June 8	June 29
Volume (gal)	1,500	340
Specific conductance (µmhos/cm @ 25°C)	127	138
Suspended solids	675	430
Total residue	1,110	770
COD Raw	94	70
Soluble	27	33
Total kjeldahl nitrogen Raw	3.4	2.8
Soluble	0.9	1.0
Total phosphorus as P Raw	1.32	1.21
Soluble	0.23	0.30
Nitrate as N	2.6	2.6
Ammonia as N	0.2	0.3
Total nitrogen	6.0	5.4

*All concentrations in milligrams per liter except as noted.

Site No. 9
Area = 9.79 acres
Cover: Corn stubble and oats

Table A11. - Chemical and Physical Quality Characteristics of Agricultural Runoff
Brookings County, South Dakota - 1971

Characteristic*		Feb 16	Feb 17	Feb 18	Feb 25	Feb 26	Mar 10	Mar 11	Mar 12	Mar 13
Volume (gal)		50,000	177,000	1,400	12,400	3,900	6,900	74,800	93,800	19,700
Specific conductance (μmhos/cm @ 25°C)		157	128	189	130	120	140	152	120	164
Suspended solids		27	24	16	16	3	11	30	40	12
Total residue		205	125	155	122	140	135	155	127	127
COD	Raw	67	57	45	66	42	93	86	46	38
	Soluble	55	37	35	52	44	71	69	39	34
Total kjeldahl nitrogen	Raw	2.0	2.5	2.2	2.5	2.0	4.5	4.0	1.7	1.7
	Soluble	2.4	2.5	2.0	2.1	2.0	4.5	3.8	1.6	1.7
Total phosphorus as P	Raw	0.58	0.44	0.46	0.43	0.27	0.56	0.60	0.45	0.32
	Soluble	0.48	0.43	0.33	0.31	0.21	0.39	0.33	0.08	0.17
Nitrate as N		0.6	0.9	1.1	0.7	0.7	0.5	0.7	0.4	0.2
Total nitrogen		2.6	3.4	3.3	3.2	2.7	5.0	4.7	2.1	1.9

*All concentrations in milligrams per liter except as noted.

Site No. 1
Area = 7.18 acres
Cover: Plowed and oats

Table A12. - Chemical and Physical Quality Characteristics of Agricultural Runoff
Brookings County, South Dakota - 1972

Characteristic*		Mar 11	May 22	May 28 AM	May 28 PM	May 29	July 28
Volume (gal)		170	1,400	2,600	1,600	2,200	51,800
Specific conductance (µmhos/cm @ 25°C)		115	358	502	538	444	136
Suspended solids		12	208	34	51	28	6,700
Total residue		107	460	378	416	346	6,730
COD	Raw	22	75	55	45	34	660
	Soluble	20	45	30	24	24	30
Total kjeldahl nitrogen	Raw	1.3	2.1	1.4	1.3	1.2	3.8
	Soluble	1.3	1.5	1.3	1.1	0.9	0.9
Total phosphorus as P	Raw	0.44	0.78	0.49	0.38	0.26	3.50
	Soluble	0.43	0.58	0.37	0.35	0.09	0.14
Nitrate as N		0.9	0.2	0.2	0.4	1.5	0.8
Ammonia as N			0.2	0.2	0.2	0.1	0.2
Total nitrogen		2.2	2.3	1.6	1.7	2.7	4.6

*All concentrations in milligrams per liter except as noted.

Site No. 2
Area = 8.77 acres
Cover: Plowed and oats

Table A13. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1972

Characteristics*	Mar 11	Mar 13	Mar 15	May 29	July 28
Volume (gal)	170	590	600	5,000	103,000
Specific conductance (μmhos/cm @ 25°C)	107	124	120	97	45
Suspended solids	19	28	59	1,360	2,940
Total residue	103	162	145	1,560	2,950
COD Raw	6	34	24	221	328
Soluble	3	25	5	22	16
Total kjeldahl nitrogen Raw	1.1	1.9	1.2	7.0	4.3
Soluble	0.9	1.7	0.9	1.3	0.6
Total phosphorus as P Raw	0.56	0.62	0.42	2.11	2.49
Soluble	0.55	0.59	0.10	0.42	0.13
Nitrate as N	0.4	1.6	1.4	1.8	0.4
Ammonia as N				0.4	0.1
Total nitrogen	1.5	3.5	2.6	8.8	4.7

*All concentrations in milligrams per liter except as noted.

Site No. 3
Area = 10.12 acres
Cover: Brome grass & alfalfa

Table A14. - Chemical and Physical Quality Characteristics of Agricultural Runoff
Brookings County, South Dakota - 1972

Characteristic*	Mar 7	Mar 10	Mar 11	Mar 12	Mar 13	Mar 14	Mar 15	July 28
Volume (gal)	257,000	16,400	48,300	6,600	23,600	1,700	1,400	27,800
Specific conductance (µmhos/cm @ 25°C)	108	116	86	174	159	137	93	73
Suspended solids	6	13	16	22	28	22	44	64
Total residue	119	129	96	249	212	148	114	141
COD Raw	51	62	37	150	123	63	24	22
Soluble	50	25	28	76	65	27	5	16
Total kjeldahl nitrogen Raw	3.3	3.6	2.3	5.6	4.4	3.5	1.1	0.8
Soluble	2.6	2.6	1.9	3.9	3.2	1.7	0.5	0.7
Total phosphorus as P Raw	0.28	0.33	0.32	0.86	0.91	0.83	0.36	0.30
Soluble	0.14	0.19	0.05	0.06	0.14	0.27	0.22	0.16
Nitrate as N	1.4	1.3	0.7	1.8	1.3	0.5	0.2	0.3
Ammonia as N								0.2
Total nitrogen	4.7	4.9	3.0	7.4	5.7	4.0	1.3	1.1

*All concentrations in milligrams per liter except as noted.

Site No. 4
Area = 8.77 acres
Cover: Brome grass & alfalfa

Table A15. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1972

Characteristic*		Mar 7	Mar 10	Mar 11	Mar 12	Mar 13	Mar 15	July 28
Volume (gal)		40,300	10,700	21,400	530	4,300	950	1,900
Specific conductance (µmhos/cm @ 25°C)		100	109	92	181	165	81	60
Suspended solids		12	13	16	18	33	54	17
Total Residue		121	130	108	190	229	116	75
COD	Raw	49	56	45	127	139	30	22
	Soluble	44	21	30	72	67	5	20
Total kjeldahl nitrogen	Raw	3.0	2.9	2.4	4.6	5.2	1.5	0.8
	Soluble	2.2	2.2	1.9	3.1	3.1	0.7	0.7
Total phosphorus as P	Raw	0.34	0.31	0.37	0.74	1.08	0.56	0.40
	Soluble	0.08	0.22	0.07	0.14	0.14	0.10	0.27
Nitrate as N		1.1	1.0	0.7	1.3	1.4	0.2	0.3
Ammonia as N								0.2
Total nitrogen		4.1	3.9	3.1	5.9	6.6	1.7	1.1

*All concentrations in milligrams per liter except as noted.

Site No. 7
Area = 15.51 acres
Cover: Grassland - Pasture

Table A16. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1972

Characteristic*	Mar 7	Mar 10	Mar 11	Mar 12	Mar 13	Mar 14	Mar 15	May 29	July 28
Volume (gal)	200,000	38,500	228,000	39,200	91,400	18,400	2,600	460	295,000
Specific conductance (µmhos/cm @ 25°C)	130	131	97	157	163	117	177	423	79
Suspended solids	3	5	18	10	24	18	15	15	60
Total Residue	126	139	101	161	198	144	147	319	125
COD Raw	53	63	45	67	110	73	39	38	60
Soluble	45	33	29	46	63	31	23	27	34
Total kjeldahl nitrogen Raw	3.2	3.3	2.5	3.3	4.7	3.9	2.6	1.6	1.8
Soluble	2.5	2.6	1.9	2.2	3.6	2.1	1.6	1.1	1.4
Total phosphorus as P Raw	0.30	0.36	0.45	0.69	0.90	0.85	0.62	0.48	0.49
Soluble	0.31	0.18	0.17	0.25	0.44	0.31	0.32	0.37	0.25
Nitrate as N	2.0	1.4	0.8	0.7	1.0	0.4	0.6	0.3	0.4
Ammonia as N								0.2	0.4
Total nitrogen	5.2	4.7	3.3	4.0	5.7	4.3	3.2	1.9	2.2

*All concentrations in milligrams per liter except as noted.

Site No. 8
Area = 18.68 acres
Cover: Plowed and weeds

Table A17. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1972

Characteristic*	Mar 6	Mar 8	Mar 9	Mar 10	Mar 11	Mar 12	Mar 13	Mar 14	Mar 15
Volume (gal)	4,400	650	2,300	36,800	147,000	37,000	81,000	29,700	4,000
Specific conductance (µmhos/cm @ 25°C)	167	225	190	152	136	169	166	224	352
Suspended solids	152	10	21	278	463	36	106	18	7
Total residue	332	190	183	711	560	190	280	211	258
COD Raw	59	37	33	129	105	50	65	41	31
Soluble	37	22	11	35	30	35	35	33	26
Total kjeldahl nitrogen Raw	3.2	2.8	4.3	3.8	2.5	2.0	2.4	2.4	2.1
Soluble	2.1	1.6	1.6	2.3	2.0	1.8	2.2	2.1	1.8
Total phosphorus as P Raw	0.58	0.32	0.34	0.83	0.64	0.35	0.34	0.39	0.28
Soluble	0.25	0.23	0.20	0.25	0.15	0.14	0.17	0.18	0.18
Nitrate as N	2.4	4.3	2.9	1.6	1.0	1.6	1.9	2.6	4.4
Total nitrogen	5.6	7.1	7.2	5.4	3.5	3.6	4.3	5.0	6.5

Table A17. - Continued

Characteristic[a]	May 1	May 12	May 22	May 23	May 24	May 28	May 29
Volume (gal)	7,200	180	1,800	5,100	22,300	43,400	134,000
Specific conductance (µmhos/cm @ 25°C)	170	204	206	460	514	429	376
Suspended solids	270	220	192	54	32	609	232
Total residue	540	578	422	401	432	914	550
COD Raw	44	55	44	53	46	115	67
Soluble	14	5	25	44	34	20	24
Total kjeldahl nitrogen Raw	1.6	1.3	2.0	2.0	1.6	3.1	1.8
Soluble	0.6	0.9	1.1	1.4	1.4	1.0	0.8
Total phosphorus as P Raw	0.74	1.07	0.52	0.35	0.24	0.76	0.42
Soluble	0.22	0.25	0.28	0.27	0.16	0.13	0.12
Nitrate as N	1.5	1.2	3.0	4.3	2.7	1.2	1.1
Ammonia as N	0.1	0.1	0.2	0.2	0.1	0.2	0.1
Total nitrogen	3.1	2.5	5.0	6.3	4.3	4.3	2.9

Table A17. - Continued

Characteristic*		June 18	June 19	July 8	July 14	July 21	July 26
Volume (gal)		450,000	124,000	55,300	1,900	99,100	139,000
Specific conductance (µmhos/cm @25°C)		219	280	181	213	284	165
Suspended solids		1,066	1,430	1,360	1,803	2,410	5,450
Total residue		1,290	1,610	1,460	1,605	2,530	5,330
COD	Raw	152	182	176	258	362	774
	Soluble	19	13	4	27	18	18
Total kjeldahl nitrogen	Raw	2.8	3.4	2.4	5.8	5.6	4.9
	Soluble	0.9	0.9	0.9	1.1	0.6	1.1
Total phosphorus as P	Raw	1.17	1.58	0.93	1.60	2.06	2.55
	Soluble	0.08	0.14	0.04	0.06	0.03	0.05
Nitrate as N		1.8	1.2	2.0	3.3	2.0	1.8
Ammonia as N		0.1	0.2	0.2	0.1	0.1	0.1
Total nitrogen		4.6	4.6	4.4	9.1	7.6	6.7

*All concentrations in milligrams per liter except as noted.

Site No. 9
Area = 18.68 acres
Cover: Plowed and weeds

Table A18. - Chemical and Physical Quality Characteristics of Agricultural Runoff Brookings County, South Dakota - 1972

Characteristic*		May 1	May 29	June 18	June 19	June 21	July 26
Volume (gal)		2,200	50,600	183,000	43,800	170	35,700
Specific conductance (μmhos/cm @ 25°C)		139	319	110	272	253	199
Suspended solids		40	45	577	90	105	182
Total residue		290	290	690	341	385	372
COD	Raw	21	34	79	23	34	44
	Soluble	4	16	13	17	21	26
Total kjeldahl nitrogen	Raw	0.9	1.2	1.7	1.4	1.4	1.2
	Soluble	0.3	0.9	0.6	0.9	0.9	0.9
Total phosphorus as P	Raw	0.36	0.24	0.82	0.37	0.69	0.51
	Soluble	0.19	0.16	0.07	0.11	0.42	0.21
Nitrate as N		0.4	1.7	0.1	0.3	2.5	0.4
Ammonia as N		0.0	0.1	0.1	0.1	0.3	0.2
Total nitrogen		1.3	2.9	1.8	1.7	3.9	1.6

*All concentrations in milligrams per liter except as noted.

APPENDIX B

Bacteriological Quality Data

Site No. 1
Area: 7.18 acres
Cover: Corn stubble and oats

Table B1. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1970			
March 23	247,000	7,370	35,800
March 31	32,400	1,680	230,000
April 1	22,000	1,800	18,200
April 2	1,910,000	7,600	164,000
April 4	12,500	36	8,480
April 5	13,600	15	57,500
Rainfall 1970			
May 31	79,000	7,900	490,000
June 15B	3,300	790	13,000

Site No. 2
Area = 8.77 acres
Cover Corn Stubble and oats

Table B2. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1970			
March 23	71,100	4,990	25,000
March 31	28,000	2,300	26,000
April 1	1,517,000	12,900	19,600
April 2	208,000	11,700	57,800
April 4	4,680	32	2,490
Rainfall 1970			
May 31	79,000	13,000	33,000
June 15A	490,000	23,000	49,000

Site No. 3
Area = 10.12 acres
Cover: Brome Grass and alfalfa

Table B3. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt			
1970			
March 23	23,000	3,100	27,600
April 1	6,530	2,140	6,390
April 2	27,600	6,390	10,700

Site No. 4
Area = 8.77 acres
Brome Grass and alfalfa

Table B4. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt			
1970			
March 23	5,600	2,050	51,000
April 1	4,550	3,082	1,840
April 4	2,300	15	1,920

Site No. 1
Area = 7.18 acres
Cover: Oat stubble and oats - '71
Plowed and corn - '72

Table B5. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1971			
February 16	16,100	80	220
February 17	1,200	230	1,720
February 18	1,300	170	330
February 25	1,300	< 100	1,300
February 26	585	< 100	230
Mar 11	16,100	5	2,400
March 12	>24,000	33	790
March 13	>24,000	23	490
Snowmelt 1972			
March 11	5,420	630	4,900
Rainfall 1972			
May 22	13,000	490	54,200
May 28 AM	54,200	54,200	10,900
May 28 PM	3,300	330	4,900
May 29	3,100	1,090	1,700
July 28	10,900	33,000	172,000

Site No. 2
Area = 8.77 acres
Cover: Oat stubble and oats - '71
Plowed and corn - '72

Table B6. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1971			
February 16	2,700	20	790
February 17	> 400	50	330
February 18	1,720	130	130
February 25	2,490	50	870
February 26	715	50	50
Snowmelt 1972			
March 11	330	40	10,900
March 13	3,300	1,300	2,300
March 15	24,000	1,720	54,200
Rainfall 1972			
May 29	13,000	4,900	33,000
July 28	348,000	8,000	49,000

Site No. 3
Area = 10.12 acres
Cover: Brome grass and alfalfa

Table B7. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1971			
February 16	2,210	1,720	2,400
February 17	3,480	3,480	2,400
February 18	16,100	16,100	2,210
February 25	700	600	2,700
February 26	2,300	650	2,300
March 10	1,700	330	2,200
March 11	3,100	---	24,000
March 12	1,400	1,410	1,700
March 13	7,900	330	1,400
Snowmelt 1972			
March 7	9,200	240	1,600
March 10	1,400	500	34,800
March 11	92,000	330	10,900
March 12	92,000	4,600	17,200
March 13	22,100	700	22,100
March 14	790	110	1,720
March 15	490	0	1,300

Table B7. - Continued

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Rainfall			
1972			
July 28	161,000	790	161,000

Site No. 4
Area = 8.77 acres
Cover: Brome grass and alfalfa

Table B8. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1971			
February 16	2,400	790	3,300
February 17	1,090	490	4,600
February 18	1,300	1,300	3,480
February 25	2,390	595	1,700
February 26	1,450	330	1,700
March 10	3,480	490	4,900
March 11	2,400	542	3,300
March 12	1,090	490	4,900
March 13	1,720	348	790
Snowmelt 1972			
March 7	2,780	240	> 1,600
March 10	800	200	10,900
March 11	13,000	330	3,300
March 12	14,100	10,900	4,900
March 13	54,200	700	4,900
March 15	700	0	4,900
Rainfall 1972			
July 28	161,000	300	161,000

Site No. 7
Area = 15.51 acres
Cover: Grassland - pasture

Table B9. - Bacteriological Quality Characteristics of Agricultural Runoff Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1971			
February 16	1,720	1,090	220
February 17	1,300	1,300	2,300
February 18	34,800	9,180	3,480
February 25	465	280	450
February 26	2,300	395	1,800
March 10	2,300	---	700
March 11	7,000	490	2,300
March 12	2,200	46	2,400
March 13	4,600	330	900
Snowmelt 1972			
March 7	> 16,000	5,420	920
March 10	4,900	1,300	2,700
March 11	27,800	1,720	1,750
March 12	10,900	3,300	4,900
March 13	7,000	4,900	7,000
March 14	7,000	330	2,300
March 15	1,720	40	490

Table B9. - Continued

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Rainfall			
1972			
May 29	54,200	4,600	17,200
July 28	161,000	161,000	91,800

Site No. 8
Area = 18.68 acres
Cover: Corn stubble and oats - '71
Plowed and idle acres - '72

Table B10. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1971			
February 16	> 16,090	130	3,300
February 17	> 16,090	50	3,480
February 18	>160,900	1,410	9,180
February 25	765,000	< 100,000	4,100
February 26	730,000	< 100,000	33,300
March 10	400,000	20	4,900
March 11	1,300,000	31	11,000
March 12	> 240,000	33	4,600
March 13	2,100,000	79	14,100
Rainfall 1971			
June 8	130,000	17,200	22,100
June 29	34,800	4,900	92,000
Snowmelt 1972			
March 6	> 16,000	49	> 1,600
March 8	160,000	80	10,900
March 9	> 160,000	20	54,200
March 10	> 160,000	0	6,300

Table B10. - Continued

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
March 11	> 160,000	110	17,200
March 12	>1,600,000	110	34,800
March 13	>1,600,000	80	17,200
March 14	1,600,000	80	4,900
March 15	348,000	0	10,900
Rainfall 1972			
May 1	3,300	200	1,300
May 12	4,900	170	13,000
May 22	34,800	700	160,900
May 23	14,100*	700*	2,300*
May 24	17,200*	790*	7,000*
May 28	34,800	10,900	54,200
May 29	34,800	1,720	91,800
June 18	160,900	34,800	27,800
June 19	24,000	790	91,800
July 8	49,000	34,800	91,800
July 14	161,000	91,800	34,800
July 21	348,000	8,000	49,000
July 26	348,000	33,000	23,000

*Delayed coliform test.

Site No. 9
Area = 9.79 acres
Cover: Corn stubble and oats - '71
Plowed and idle acres - '72

Table B11. - Bacteriological Quality Characteristics of Agricultural Runoff, Brookings County, South Dakota

Date	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Streptococcus (MPN/100 ml)
Snowmelt 1971			
February 16	> 16,090	230	1,300
Febuary 17	16,100	330	1,300
February 18	>160,900	220	3,480
February 25	979,000	< 10,000	2,940
February 26	730,000	< 10,000	5,420
March 10	1,090,000	70	13,000
March 11	340,000	33	22,100
March 12	1,300,000	2,400	7,900
March 13	460,000	49	3,100
Rainfall 1972			
May 1	110	20	790
May 29	34,800	3,300	3,300
June 18	91,800	34,800	160,900
June 19	13,000	1,090	17,500
July 21	91,800	7,900	161,000
July 26	161,000	7,900	91,800

APPENDIX C

Pesticide Data

Table C1. - Results of Pesticides Analyses For Phase I

(All values in ppb, unless noted.)

Date	Site 1	Site 2	Site 3	Site 4
3/23/70	*	*	*	Aldrin 0.07 Dieldrin 0.08 DDE 0.21 DDD 0.17
4/1/70	Aldrin 0.17 DDE 0.07	DDT 0.13	*	
4/2/70	*	(Lost)		
5/31/70	Heptachlor 0.25 Aldrin 0.29	(Duplicate) Aldrin 0.17 Aldrin 0.30		
6/15/70	*	*		

*Below analytical test limits.

Table C2. - Results of Pesticides Analyses on Filtered Samples
Phase II

(All values in ppb, unless noted.)

Date	Site 1	Site 2	Site 3	Site 4	Site 7	Site 8	Site 9
2/16/71	*	*	*	*	*	*	*
2/17/71	*	*	*	*	*	*	*
2/18/71	*	*	*	*	*	*	*
2/25/71 & 2/26/71	.15DDD .2 DDT	*	.12 DDD	*	.27 DDD .14 DDT	.18 DDD .10 DDT	.18 DDD .17 DDT
3/10/71 to 3/13/71					.14 DDE		
3/11/71 to 3/13/71	.33 DDT						
6/8/71						.2 DDE .1 DDT	
3/6/72						*	
3/7/72			*	*	*		
3/8/72 & 3/9/72						*	
3/11/72	*						
3/10/72 to 3/13/72			*	*	*	*	
3/14/72 & 3/15/72			*		*	*	
3/15/72				*			

Table C2. - Continued

(All values in ppb, unless noted.)

Date	Site 1	Site 2	Site 3	Site 4	Site 7	Site 8	Site 9
5/1/72						*	*
5/12/72						*	
5/22/72	*					.06 DDE	
5/23/72						*	
5/24/72						*	
5/28/72 AM	.24 DDE .13 DDD .10 DDT					.06 Aldrin .17 DDE	
5/28/72 PM	.22 DDE					.08 DDE	
5/29/72	*	*			*	*	*
7/8/72						.61 Aldrin .12 DDE	
7/21/72						*	*
7/26/72						.10 DDE	
7/28/72	*	*	.15 DDE	.19 DDE	.06 DDE		

*Below analytical test limits.

Table C3. - Results of Pesticides Analyses on Filtered Samples Phase II

(All values in ppb, unless noted.)

Date	Site 1	Site 2	Site 7	Site 8	Site 9
6/8/71				10 Aldrin 5 DDE 1 Dieldrin 10 DDT	
6/29/71				3.4 Lindane 5.8 Aldrin 22.9 DDE 5.3 Dieldrin	
5/1/72				*	*
5/12/72				*	
5/22/72				*	
5/24/72				*	
5/28/72 AM	100 Aldrin 23 DDE 42 DDT				
5/28/72 PM	262 Aldrin			5 Aldrin 16 DDE	
5/29/72	10 Aldrin 13 DDE 19 DDT	40 Aldrin	59 Aldrin	194 Aldrin	10 Aldrin 12 DDE
6/18/72 & 6/19/72				*	14.17 ppm Atrazine
7/8/72				290 Aldrin 170 DDE	
7/14/72				*	
7/21/72				*	*

Table C3. - Continued

Date	Site 1	Site 2	Site 7	Site 8	Site 9
7/26/72				89 Aldrin	
7/28/72	89 Aldrin 12 DDE 17 DDT	*			

*Below analytical test limits

APPENDIX D

Mean Concentrations of Parameters

Table D1. - Mean Concentrations of Agricultural Runoff Parameters
Brookings County, South Dakota

Site & Time	Parameter					
	Total Residue (mg/l)	Suspended Solids (mg/l)	Specific Conductance (μmhos/cm @ 25°C)	Total Phosphorus (mg/l) Raw	Total Phosphorus (mg/l) Soluble	Nitrate (mg/l N)
Site 1						
Snowmelt '71	171	51	132	0.47	0.35	0.5
Snowmelt '72	107	12	115	0.44	0.43	0.9
Rainfall '72	1670	1400	396	1.08	0.31	0.6
Site 2						
Snowmelt '71	158	29	134	0.41	0.30	0.5
Snowmelt '72	137	35	117	0.53	0.41	1.1
Rainfall '72	2260	2150	71	2.30	0.27	1.1
Site 3						
Snowmelt '71	125	17	121	0.47	0.19	0.6
Snowmelt '72	152	22	125	0.56	0.15	1.0
Rainfall '72	141	64	73	0.30	0.16	0.3
Site 4						
Snowmelt '71	118	13	111	0.41	0.19	0.6
Snowmelt '72	149	24	121	0.57	0.13	1.0
Rainfall '72	75	17	60	0.40	0.27	0.3

Table D1. - Continued

Site & Time	Parameter Total Residue (mg/l)	Suspended Solids (mg/l)	Specific Conductance (µmhos/cm @ 25°C)	Total Phosphorus (mg/l) Raw	 Soluble	Nitrate (mg/l N)
Site 7						
Snowmelt '71	154	21	154	0.74	0.34	0.8
Snowmelt '72	145	13	139	0.60	0.28	1.0
Rainfall '72	222	38	251	0.49	0.31	0.4
Site 8						
Snowmelt '71	150	35	135	0.40	0.25	0.8
Snowmelt '72	324	121	198	0.45	0.19	2.5
Rainfall '71	940	552	133	1.27	0.27	2.6
Rainfall '72	1360	1160	285	1.08	0.14	2.1
Site 9						
Snowmelt '71	143	20	144	0.46	0.30	0.6
Rainfall '72	395	173	215	0.50	0.19	0.9

Table D1. - Continued

	Parameter					
	Total Kjeldahl Nitrogen (mg/1 N)		COD (mg/1)			
Site & Time	Raw	Soluble	Raw	Soluble	Ammonia (mg/1 N)	Number Of Samples
Site 1						
Snowmelt '71	1.3	0.9	35	24	-	8
Snowmelt '72	1.3	1.3	22	20	-	1
Rainfall '72	2.0	1.1	174	31	0.2	5
Site 2						
Snowmelt '71	1.2	1.0	34	25	-	5
Snowmelt '72	1.4	1.2	21	11	-	3
Rainfall '72	5.7	2.0	275	19	0.2	2
Site 3						
Snowmelt '71	2.5	1.7	56	37	-	9
Snowmelt '72	3.4	2.3	73	39	-	6
Rainfall '72	0.8	0.7	22	16	0.2	1
Site 4						
Snowmelt '71	2.2	1.6	50	35	-	9
Snowmelt '72	3.3	2.2	74	40	-	6
Rainfall '72	0.8	0.7	22	20	0.2	1
Site 7						
Snowmelt '71	3.4	2.6	73	48	-	9
Snowmelt '72	3.4	2.2	64	39	-	7
Rainfall '72	1.7	1.2	49	30	0.3	2

Table D1. - Continued

Site & Time	Parameter					
	Total Kjeldahl Nitrogen (mg/1 N)		COD (mg/1)		Ammonia (mg/1 N)	Number Of Samples
	Raw	Soluble	Raw	Soluble		
Site 8						
Snowmelt '71	2.3	2.2	57	47	-	9
Snowmelt '72	2.8	1.9	61	29	-	9
Rainfall '71	3.1	1.0	82	30	0.2	2
Rainfall '72	2.9	1.0	179	20	0.1	13
Site 9						
Snowmelt '71	2.6	2.5	60	48	-	9
Rainfall '72	1.3	0.7	39	16	0.1	6

APPENDIX E

Annual Contributions

Table E1. - Yearly Runoff Contributions of Agricultural Runoff Constituents
Brookings County, South Dakota

		Constituent (lb/acre/yr)						
Site	Year	Total Residue	Suspended Solids	Chemical Oxygen Demand	Total Phosphorus as P	Total Kjeldahl Nitrogen	Nitrate-N	Total Nitrogen
1	1971	11.7	3.9	2.4	0.03	0.10	0.03	0.13
	1972	408	404	40.1	0.21	0.24	0.06	0.30
2	1971	3.3	0.6	0.7	0.01	0.02	0.01	0.03
	1972	294	296	33.2	0.25	0.45	0.05	0.50
3	1971	37.4	5.1	14.7	0.11	0.68	0.22	0.90
	1972	39.8	4.3	16.9	0.11	0.98	0.39	1.37
4	1971	25.9	3.5	11.4	0.10	0.65	0.15	0.80
	1972	9.5	1.1	4.1	0.03	0.22	0.07	0.29
7	1971	40.4	7.21	19.8	0.19	0.95	0.23	1.17
	1972	63.4	13.7	29.7	0.24	1.04	0.48	1.52
8	1971	59.8	17.5	23.1	0.16	0.86	0.26	1.12
	1972	953	840	129	0.72	1.95	1.05	3.00
9	1971	52.5	10.3	22.7	0.18	0.94	0.26	1.20
	1972	145	101	16.0	0.17	0.41	0.11	0.52

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